

MINING engineering

OCTOBER 1954



ORE DRESSING PROGRESS

Lower Pumping Costs

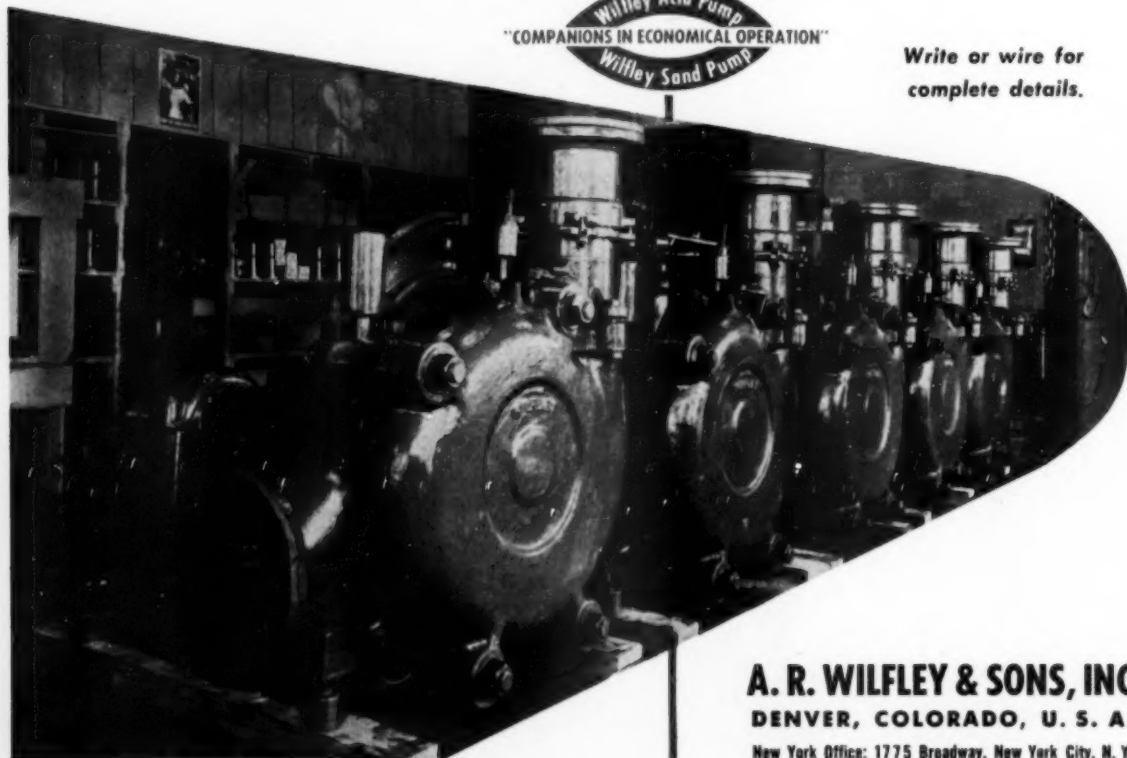
IN HEAVY MEDIA SERVICE

These Wilfley 8 inch Model "K" Sand Pumps are specifically designed for rugged, heavy duty service in a new coal preparation plant. These dependable, highly efficient pumps deliver continuous, trouble-free performance at low cost without media loss, leakage or dilution.

- Individual engineering on every application
- Cost-saving efficiency
- Reduced power and maintenance costs
- Continuous operation without attention
- Minimum replacement of parts
- Designed for simple installation
- Economical pump size for every requirement



*Write or wire for
complete details.*



A. R. WILFLEY & SONS, INC.
DENVER, COLORADO, U. S. A.
New York Office: 1775 Broadway, New York City, N. Y.



MINING engineering

VOL. 6 NO. 10

OCTOBER 1954

ALVIN S. COHAN
Manager of Publications
CHARLES M. COOLEY
Acting Editor

RIXFORD A. BEALS
Associate Editor

M. A. MATZKIN
News Editor

SCOTT CONKLING M. E. SHERMAN
Assistant Editors

GRACE PUGSLEY, Production Manager;
W. J. SEWING, Asst. Prod. Mgr.

TECHNICAL PUBLICATIONS COMMITTEE

ROBERT H. ABORN.....Chairman
E. J. KENNEDY, JR.....Secretary

DIVISIONAL PUBLICATIONS COMMITTEE CHAIRMEN

R. V. PIERCE.....Mining
CHARLES MEYER.....Geology
DART WANTLAND.....Geophysics
N. ARBITER.....Beneficiation
H. P. GREENWALD.....Coal
BRUCE C. NETSCHERT.....Indus. Minerals
ROLAND D. PARKS.....Education
H. A. FRANKE.....Mineral Economics

FRED STANLEY
Eastern Advertising Manager

BOB WILSON
Mid-Western Advertising Manager
84 E. Randolph St., Chicago

MCDONALD-THOMPSON
Western Advertising Representatives
625 Market St.
San Francisco 4, Calif.

The AIME publishes Mining Engineering
Journal of Metals
Journal of Petroleum Technology

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: Pennsylvania 6-9220. Subscription \$8 per year for non-AIME members in the U. S. & North, South & Central America; \$10 foreign; \$6 for AIME members, or \$4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies \$.75; single copies foreign \$1.00, special issues \$1.50. The AIME is not responsible for any statement made or opinion expressed in its publication. Copyright 1954 by the American Institute of Mining and Metallurgical Engineers, Inc. Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC.



COVER

For this month's cover, Herb McClure draws upon a woodcut from Georgius Agricola's *De Re Metallica* illustrating ore dressing in the 16th century. On page 976 C. Harry Benedict traces *The Five Major Advances in Nonferrous Ore Dressing* in the 20th century.

FEATURES

Personnel Service	942	Trends	970
Books	950	Drift	973
Letters to the Editor	952	AIME News	1021
Meet the Authors	954	Personals	1029
Manufacturers News	956	Professional Services	1034
Reporter	957	Coming Events	1036
Mining News	961	Advertisers' Index	1036

ARTICLES

Reserve's E. W. Davis Works Installs New Heat Hardening Process for Taconites	974
The Five Major Advances in Nonferrous Ore Dressing	C. H. Benedict 976
Steadily Growing Southeastern Tungsten Production	John V. Hamme 978
Rocky Mountain Industrial Minerals Conference	
Industrial Water	Elroy Nelson 983
Natural Gas	H. F. Hillard 985
Statistical Analysis Points the Way for \$\$\$\$ Savings in Beneficiation	A. C. Dorenfeld 986

TRANSACTIONS

Safety Factor Characteristic Curves. Application to Mine Hoisting Ropes	W. A. Boyer 989
Phosphate Rock as an Economic Source of Fluorine	W. L. Hill and K. D. Jacob 994
Analysis of Rod Milling Variables	Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom 1001
Natural Abrasives in Canada	T. H. Jones 1010
Evaluating the Performance of a Coal Cleaning Unit	J. Visman 1015

— Personnel Service —

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., New York 18; 100 Farnsworth Ave., Detroit; 57 Post St., San Francisco; 84 E. Randolph St., Chicago 1. Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for \$3.50 a quarter, \$12 a year.

— MEN AVAILABLE —

Engineer-Geologist, 42, married. Fifteen years varied experience including 3 years in Alaska as junior mining engineer and geologist, 3 years as engineer in aircraft factory, 3 years surface and underground geological mapping in western U. S., 3 years in Australia and adjacent islands, and 3 years in India making geologic reconnaissance surveys. Prefers foreign or western U. S. M-100.

Mining Engineer, 34, married, perfect health. Broad experience as mine superintendent, engineer-geologist. Familiar with most types un-

derground mining, milling, property examinations, etc. Extremely cost-conscious, excellent labor relations and very progressive. Prefers East but will go anywhere in U. S. Available 30 days. M-101.

— POSITIONS OPEN —

Geologist, with metal mining and exploration experience in foreign fields covering lead, zinc, copper, chrome, etc. Salary, \$12,000 to \$15,000 a year. Location, Turkey. F428.

Exploration Geologist, under 55, with at least 5 years foreign mineral survey experience for field exploration work. Salary, over \$8000 a year. Location, Indonesia. F420.

Metallurgical Engineer, with experience in mineral dressing or process metallurgy for uranium research and development on various types of ores. Salary open. Location, Massachusetts. W416.

Mine Manager, with at least 10 years metal mining and milling experience for tin, lead, silver property at high altitude. Must speak Spanish. Salary open. South America. F396.

Mine Manager for operating lead-zinc mine in Central America. Knowledge Spanish, operating experience Latin America, required. Liberal salary to right man. State salary required. W395.

Product Engineer, with milling and marketing experience in nonmetallurgical field for rock products development and sales promotion work. Salary, \$10,000 to \$12,000 a year. Location, California. W427.

Mill Foreman, young, graduate in ore dressing, experienced in screens, jigs, Humphreys spiral, air-table and magnetic separation for columbite-tantalite mill. Must be single. Salary, \$4800 a year. Location, South America. F408.

MINE SUPERINTENDENT

Exceptional opportunity for very hard-working mining engineer with strong interest in geology, 30 to 40 yr. old, with demonstrated supervisory ability and experience particularly underground mining methods at mine operated by chemical company to insure mercury supply. Write fully, including photograph, resume of college records, experience and references to Dr. S. J. Buckman, Buckman Mines, Geyser Road, Cloverdale, Calif.

WANTED: Graduate engineer qualified as superintendent for gas-fired vertical kiln lime plant. Must be willing to assume responsibility and capable of developing into company production manager. Should be interested in future development rather than starting salary. Job offers plenty of hard work but wonderful opportunity for the right man. Reply giving age, education, experience, and salary required. Full details in first letter. All replies maintained confidential.

Box J-15 AIME
29 West 39th St., New York 18, N. Y.

ARE YOU THIS MAN?

We are seeking a man to fill an important position with very considerable prospects.

His experience should include knowledge of methods and equipment required to deal with problems of filtering, leaching, calcining and handling solids and liquids.

His qualifications must be similar to those that should be possessed by a highly efficient manager or assistant manager of a mine mill.

He will be expected to assist in the development of a new process, its installation, and to assume responsibility for its subsequent operation. The nature of the work requires a keen sense of the economics involved in the process and the ability to accurately assess capacity of plant after installation.

Salary open.

Box J-16 AIME
29 West 39th St., New York 18

**DETECT URANIUM DEPOSITS
100 TIMES EASIER!**



Here is the ideal field instrument for Uranium prospecting. It's ultra-sensitive, low in cost, lightweight and small in size.

The model 117 "Special Scintillator" is made by Precision Radiation Instruments, Inc., manufacturers of the famous Model 111 "Scintillator".

Contact your nearest dealer or write direct for free complete catalog on instruments for detecting Uranium and other metals.

ONLY
\$299.50

PRECISION RADIATION INSTRUMENTS, INC.
2235 ME S. La Brea, Los Angeles 16, Calif.
Please send Free Catalog.

Name _____
Address _____
City _____ Zone _____ State _____
WORLD'S LARGEST MANUFACTURERS OF PORTABLE RADIATION INSTRUMENTS

AVAILABLE

MINING ENGINEER—Interested in management-operations, registered, age 36, married. Business training, ability to oversee examination, evaluation, layout, development, and operation of underground and surface mining. Thorough experience and knowledge of labor, all phases of mining, latest methods of mechanical mining. Conscious of production-cost, strong in statistical and capital cost. Willing to shoulder responsibility.

Box 100, AIME
29 West 39 St., New York 18, N. Y.

RESEARCH AND DEVELOPMENT METALLURGISTS

New career positions in leading independent research organization for graduate metallurgists with interests and appropriate experience in extractive metallurgy or other minerals processing phases. Merit promotions and excellent opportunities for professional achievement. Please reply immediately for prompt, confidential consideration to

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio



**Handling
Iron Ore Tailings
at 20° Below**

**with the
Dorr 4-Arm Torq Thickener**

This 150' dia., extra heavy duty Dorr Torq Thickener is in operation at the Pilotac Concentrator of the Oliver Iron Mining Division of U. S. Steel Corporation, Mountain Iron, Minnesota. It thickens 100 to 120 long tons per hour of minus 100 mesh tailings. Feed contains 7 to 12% solids; overflow rate is approximately 4500 gals. per min. Thickener underflow contains about 50% solids.

Two long arms rake only the outer section of the tank floor. Two short arms take over the load

in the inner section, raking all solids to a conventional centercone discharge. All 4 arms are provided with the exclusive Dorr Torq feature which reduces overload by continuous raking action, without the danger of stalling and damage to the unit.

For more information about the advantages of the 4-Arm Torq and the complete Dorr Thickener line, write for a copy of Bulletin No. 3001, The Dorr Company, Stamford, Conn.
In Canada, 26 St. Clair Avenue, East, Toronto 5.

Torq is a trademark of The Dorr Company, Reg. U. S. Pat. Off.



Better tools TODAY to meet tomorrow's demand

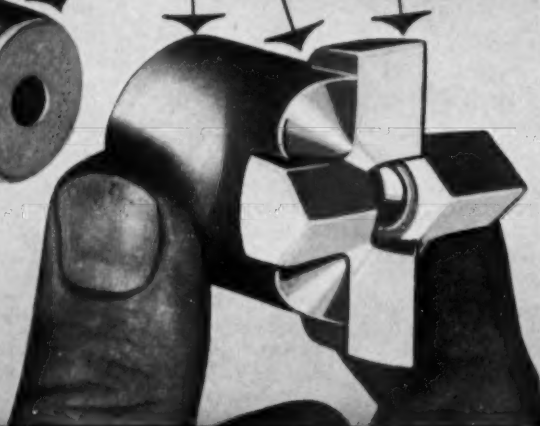
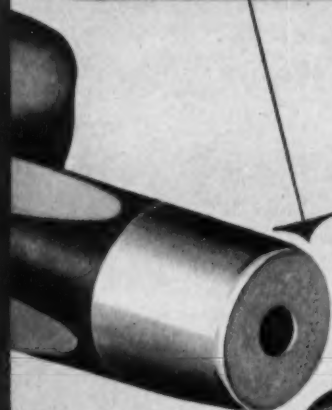
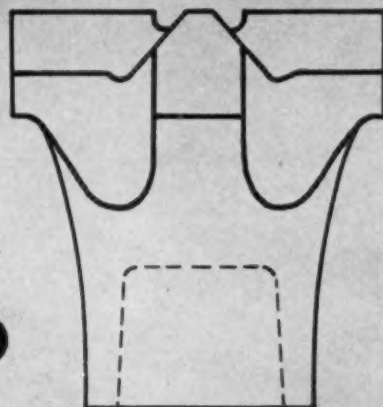
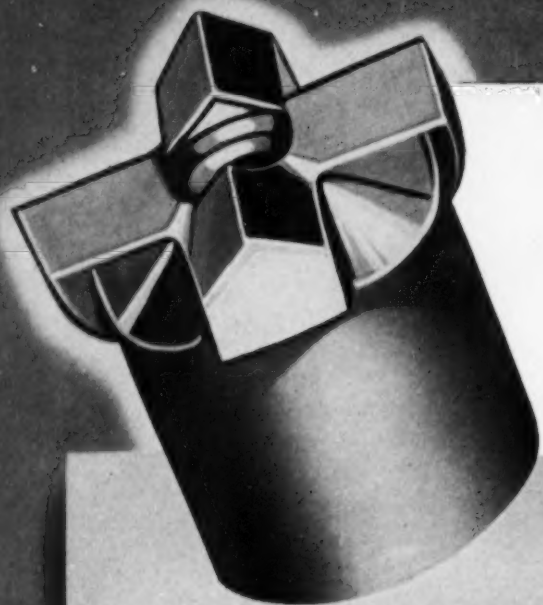
D O R R

WORLD - WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.
Offices, Associated Companies or Representatives in principal cities of the world.



Here's another



The union of the bit and the rod after drilling has a cohesive strength of several tons . . . A sharp blow of sufficient weight on the end of the bit skirt will serve to detach the bit from the rod.

SPECIFICATIONS

Mines everywhere cut drilling costs with CRD DETACHABLE DRILL BITS • 4 - Wing Type - Center Hole - Side Hole

Class "A" Bits	Size	Color	Class "B" Bits	Size	Color
For class "A" drill steel connection on any steel. Best suited to 7/8" steel.	1-1/4	Aluminum	For class "B" drill steel connection on any steel. Best suited to 1", 1 1/8" and 1-1/4" steel.	1-7/16	Orange
	1-5/16	Pink		1-1/2	Green
	1-3/8	Deep Green		1-9/16	Yellow
	1-7/16	Brown		1-5/8	White
	1-1/2	Grey		1-11/16	Black
	1-9/16	Maroon		1-3/4	Red
	1-5/8	Deep Blue		1-13/16	Blue
				1-7/8	Tan
				1-15/16	Plain
				2	Pink
				2-1/8	Maroon
				2-1/4	Aluminum

Cans are labeled showing size of steel socket, gauge of bit, and color.

way to cut drilling costs!

Use Le Roi-CLEVELAND one-use CRD Detachable Bits



Lower cost per foot of hole — that's the goal of everyone who has rock to drill. And that was the goal of Le Roi-CLEVELAND engineers, too. They didn't fool around with the problem either.

Fifty years of experience in designing rock drills was put to work. The result — a one-use detachable bit that can save you money in a wide variety of applications.

This designing job wasn't done overnight. You can't produce the results our engineers were after in such a short time. Instead, these bits were put to work—and, for a number of years they have helped reduce drilling costs materially in mines, in quarries, and on construction jobs.

That's why we offer them to you now — with complete confidence in their ability to help you improve your rock-drilling cost picture.

These Features Mean Lower Drilling Costs for You

Faster Drilling Speed — Special offset gauge feature, which permits the use of thinner wings and a steeper reaming angle, greatly reduces binding and provides ample

clearance for cuttings. Result is a free, fast-cutting chiseling action that gives you greater drilling speed.

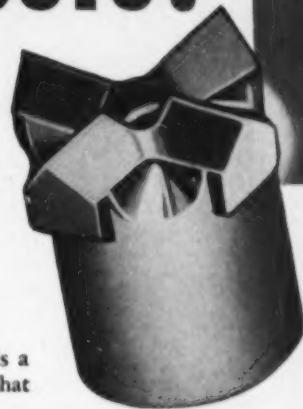
Less Drill-Steel Breakage — The method of attachment used with the CRD bit eliminates threads on the drill rod. Since a drill rod is only as strong as the root diameters of its threads, the tapered threadless CRD design provides longer drill-steel life — reduces drill-steel handling and reconditioning costs.

Lower Rock Drill Repair Costs — Because the CRD bit design reduces binding in the hole, there is less strain on the rotation parts of your rock drills. Rifle bars, rifle nuts, and chucks last longer. You get more drilling done at lower cost.

Since no special equipment is needed to thread rods, you owe it to yourself to try a can of CRD bits. They're ideal for roof bolting and for use in your stopes as well as in your headings. A short trial will give you first hand information on the ability of these bits to cut drilling costs in your property as they have in so many others.

Bulletin RD-29 gives detailed information. A copy is yours for the asking — just write for it.

RD-29

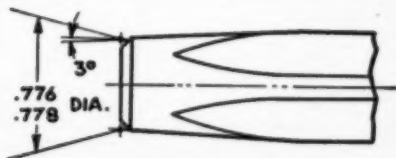


CLEVELAND ROCK DRILL DIVISION Le Roi Company

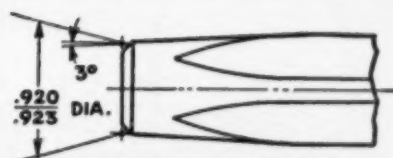
A Subsidiary of Westinghouse Air Brake Co.

12500 BEREA ROAD • CLEVELAND 11, OHIO

Plants: Milwaukee, Wis. • Cleveland — Greenwich — Dunkirk, Ohio • Coldwater, Mich.



Taper shank dimensions for $\frac{3}{8}$ " steel.
Class A Bits

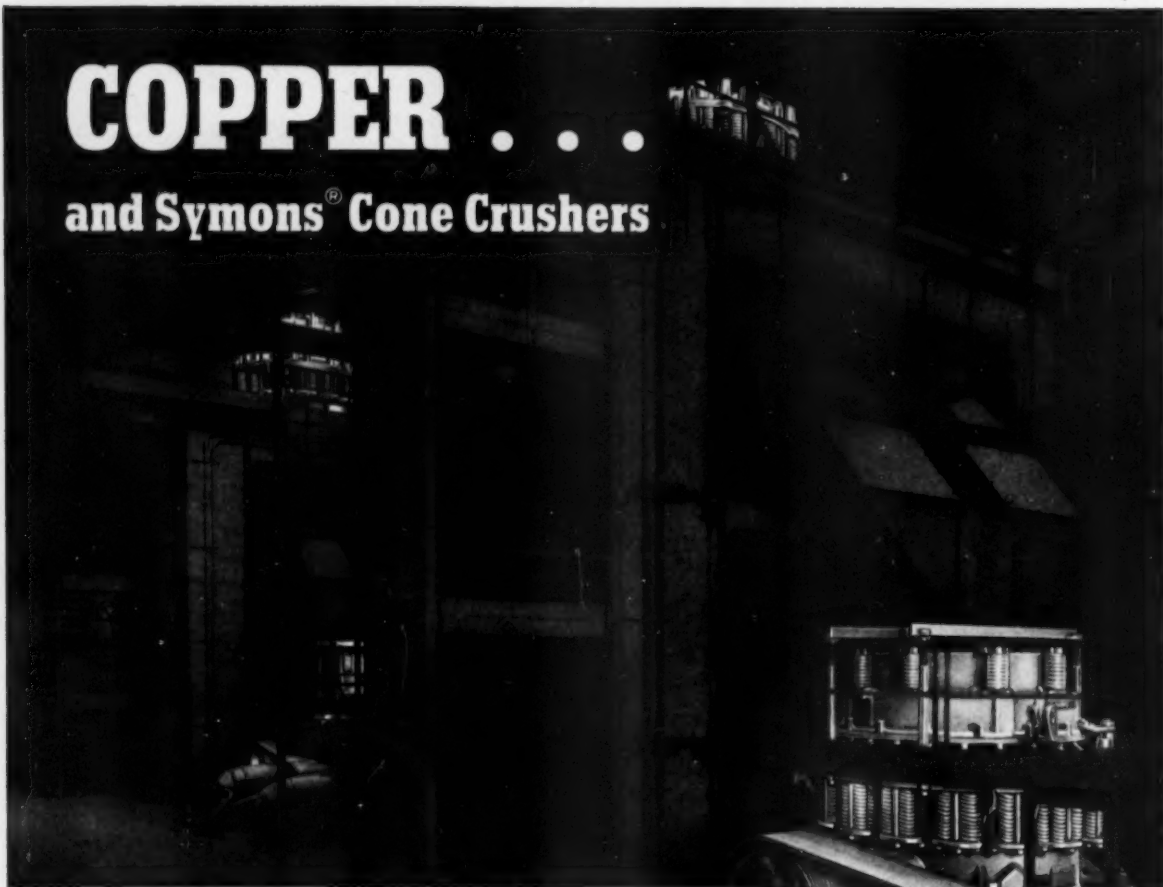


Taper shank dimensions for 1" hex,
1" Q.O., $1\frac{1}{8}$ " and $1\frac{1}{4}$ " rd. steel.
Class B Bits

The taper attachment shank used with the CRD bit is easy to make. You need no die or other expensive threading equipment. Several simple, low-cost methods can be used for preparation — grinding, forging or machining.

COPPER . . .

and Symons® Cone Crushers



COPPER...and Symons® Cone Crushers

Symons Cone Crushers . . . the machines that revolutionized crusher practice . . . have long proved their efficiency, dependability and economy in the profitable reduction of ores and minerals the world over. In the case of COPPER, it is significant that more than 90% of the world's production passes through Symons Cone Crushers. Throughout the entire COPPER industry, the new and repeat orders for these crushers are continued evidence of the satisfaction given in fine reduction crushing service. The outstanding performance of Symons Cones in delivering a finely crushed product in greater capacities and at lower cost makes them the leading choice of the world's outstanding mining companies.

NORDBERG MFG. CO., Milwaukee, Wisconsin

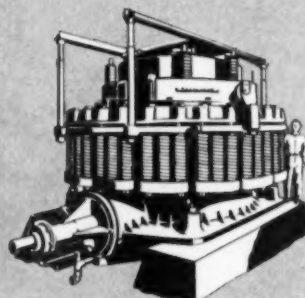


NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

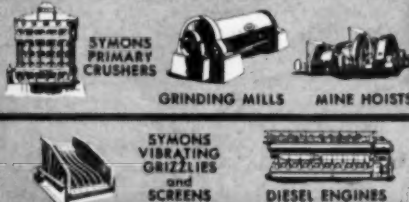
NEW YORK • SAN FRANCISCO • DULUTH • WASHINGTON
TORONTO • MEXICO, D.F. • LONDON • JOHANNESBURG



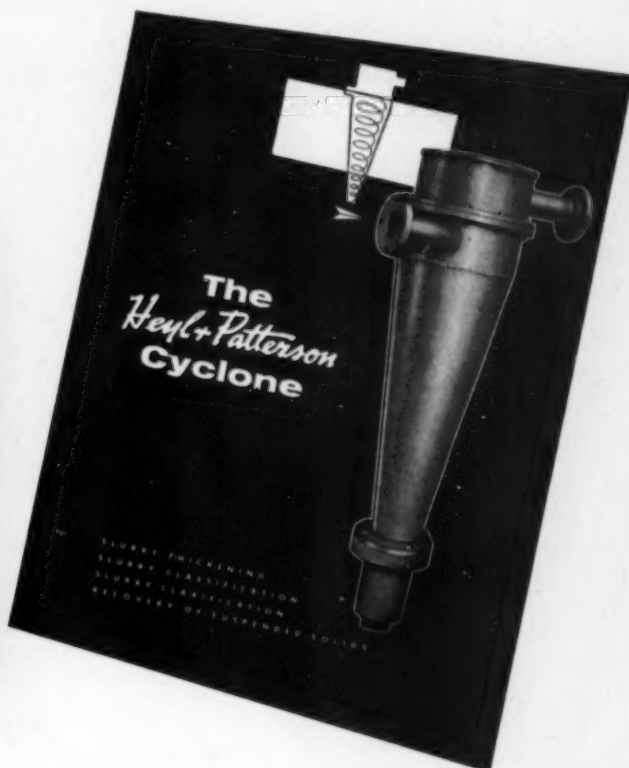


Symons Cone Crushers are built in Standard, Short-head and Intermediate types with crushing heads from 22" to 7' in diameter — in capacities from 6 to 900 tons per hour.

SYMONS . . . A REGISTERED NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD.



**Of Vital Interest
to
Preparation
and
Processing
Men**



This new 20 page Heyl and Patterson Booklet is crammed with information on the H & P Cyclone. It shows how the H & P Cyclones operate, provides flow diagrams and photographs from actual installations,

If you feel that you have a possible Cyclone application, contact the H & P Research Department. If our experienced engineers don't know the answers to your problem immediately, they have complete facilities and data to obtain these answers. You can be assured of their complete cooperation.

and gives operating data from typical applications in the coal, mining and chemical processing industries.

There are probably places in your plant where H & P Cyclones could be used to advantage to replace or supplement other more costly equipment. The obvious benefits of high efficiency, low cost and small amount of space used may open fields of application in which the Cyclone has never been tested.

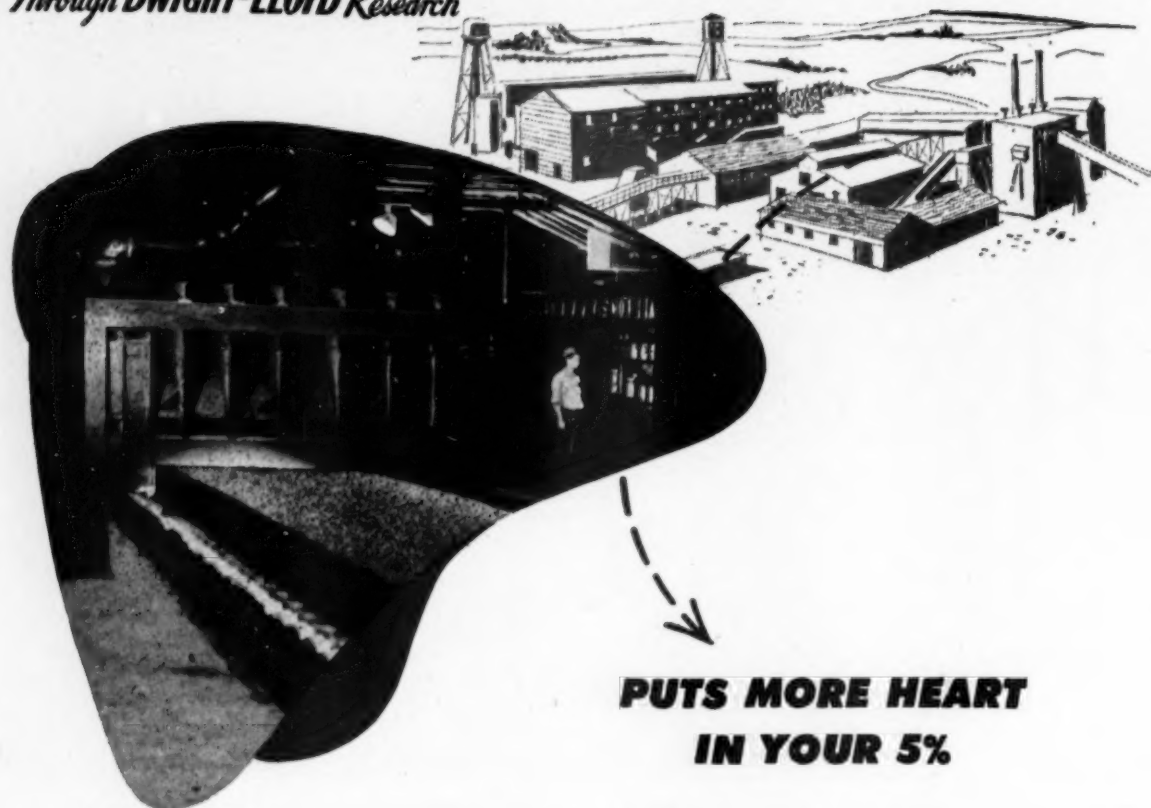
The very nature of the H & P Cyclone makes it something that every processing man should know about. You will find this booklet worthy of your deep study. It belongs in your permanent file for future reference. Write today for Booklet CT-954.

Cyclone Thickeners
Thermal Dryers
The Drying Dutchman
Reinforced Centrifugal Dryer
Thorsten Coal
Sampling System
Rotary Mine Car Dumpers
Coal Crushers
Coal Preparation Plants
Bradford Breakers

Heyl + Patterson, Inc.
"SINCE 1887"

55 FORT PITT BLVD. PITTSBURGH 22, PA.

*Revolution in Sintering
Through DWIGHT-LLOYD Research*



FEATURES OF THE NEW DWIGHT-LLOYD MACHINES

ROWEN WINDBOX SEAL* — completely eliminates air leakage between pallets and windbox, resulting in a more uniform product, greater production and lower operating costs.

COMPOUND DISCHARGE CURVE* — eliminates spillage, controls pallet drop, reduces pallet wear.

UPPER WINDBOX — permits up-draft or down-draft operation, adding great flexibility to installation. Can be used to recirculate hot gases, reducing fuel requirements for the charge and also lowering plant heating costs.

ROLL FEEDERS — assure an even distribution of charge on pallets.

*Patented

PUTS MORE HEART IN YOUR 5%

Getting a good sinter, at low cost, is more dependent on the sintering machine than any other part of the plant installation. Yet this vital heart of the installation represents only 5% of your plant investment.

The new Dwight-Lloyd machine was designed to add even greater value to this important 5%. It incorporates many engineering advances which improve the sinter quality and reduce production costs. With these features, the Dwight-Lloyd machine is establishing new standards for output and quality.

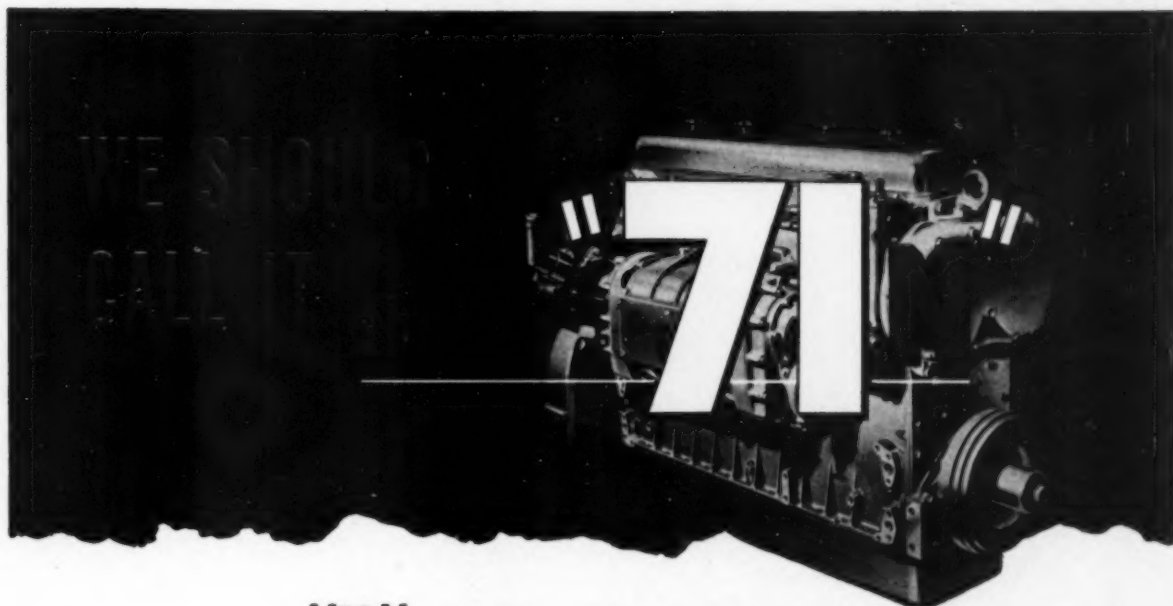
The constant improvement of the Dwight-Lloyd machine has been the objective of years of research by our engineers. That's why it represents the finest in modern, economical sintering.

Write for detailed information on the new Dwight-Lloyd sintering machines.



DWIGHT-LLOYD, Inc.
DIVISION OF SINTERING MACHINERY CORPORATION

125 Sinter Ave., Netcong, New Jersey



"N" FOR NEW—New Where It Counts Most

You don't have to be an old-timer to remember when the first General Motors Series 71 Diesel was introduced. We called it the "71" in 1938 and we call it the "71" today.

But in 17 years these design improvements from top to bottom have given operators higher horsepower, lower fuel consumption and longer engine life. And now, a whole series of new improvements has made this fast-stepping, compact, 2-cycle Diesel better than ever.

NEW 17 TO 1 COMPRESSION gives better fuel economy, squeezing more power from every gallon of fuel.

NEW "FIGURE 8" CYLINDER LINERS give you a cleaner burning, more efficient engine. Air intake area is increased 32% for more complete fuel burning and better exhaust.

NEW IMPROVEMENTS IN PISTON PIN, PIN RETAINER AND CAM FOLLOWER DESIGN mean longer life, less maintenance cost. High-valve unit injectors last longer because the valve assembly is away

from high cylinder temperature areas. Hard-chrome steel "Lite-Tite" piston rings resist wear; are tougher and more flexible and give many more hours of service.

And—best of all—in your next overhaul you can incorporate any or all of these new improvements in any GM Series 71 Diesel engine you're operating today. "The Inside Story" tells you how these new improvements can help cut your costs and speed your jobs. Mail the coupon today for your copy.

DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS • DETROIT 28, MICHIGAN
Single Engines . . . 30 to 300 H.P. • Multiple Units . . . Up to 893 H.P.

It Pays to STANDARDIZE on



Write For Booklet

DETROIT DIESEL ENGINE DIVISION
General Motors Corporation
Detroit 28, Michigan

Please send me booklet "The Inside Story"

Name: _____
Position: _____
Company: _____
Address: _____
City & State: _____

Books for Engineers

Data Book for Civil Engineers: Vol. I, Design, \$10.00, 521 pp., 2nd ed., 1952; **Vol. II, Specifications and Costs**, \$5.00, 506 pp., 2nd ed., 1952; **Vol. III, Field Practice**, by Elwyn E. Seelye, John Wiley & Sons Inc., \$7.50, 394 pp., 2nd ed., 1954.—With the recent publication of the third volume this entire set is now up-to-date. Added to this volume are some practical methods of field erection, common types of cracks and defects in brick masonry, new tables on metal corrosion, including the galvanic series, methods of identifying steel and iron by means of sparks, and coverage of soil behavior. There are also check lists for work on concrete, masonry, structural steel, grading, bituminous paving, sanitary construction, and pipe laying.

Historical Development of Inclusion Thermometry, by F. G. Smith, University of Toronto Press, \$4.50 Can., 149 pp., 1953.—A survey of the litera-

ture on determining the temperature and pressure of deposition of minerals from measurements of foreign inclusions. The first section summarizes published data from 1818 to 1953, while the second critically reviews present knowledge of the subject under four headings: types of inclusions in crystals, formation of inclusions, solutions of mineral growth, and inclusion geothermometry. Author and subject bibliographies.

The Coalfields of Great Britain, edited by Arthur Trueman, Edward Arnold Ltd., London, available in the U. S. from St. Martin's Press Inc., \$17.50, 396 pp., 1954.—Geology of coal and coal field structures and resources. General chapters on coal field rocks, fossils, and origins by the editor, and separate chapters on particular fields prepared by various authors.

Please Order the Publications Listed Below from the Publishers

Handbook of Cretaceous Foraminifera of Texas, by Donald L. Frizzell, Bureau of Economic Geology, University of Texas, University Station, Box 8022, Austin 12, Texas, \$2.75 cloth bound, \$1.75 paper bound, 232 pp., 4 fig., 21 plates.—Of primary interest to advanced college-level students and commercial laboratory micropaleontologists, this study should also be useful to specialists.

Atlas of Mineral Resources of Indiana, Map No. 5. Map showing railroads in Indiana, 15¢. **Atlas of Mineral Resources of Indiana, Map No. 6.** Map showing location of industrial sand, marl, peat, mineral wool, cement, and lime operations in Indiana, 15¢. **Report of Progress No. 6**—An analysis of selected Indiana coals by the particle count method, by Ranard Jackson Pickering, 50¢. A preliminary report on a method of determining the percentage of vitrain, fusain, and clarain in Indiana coals. Publications Office, Geological Survey, Indiana Dept. of Conservation, Bloomington, Ind. Please send money order or check.

The Fife Coal Company Limited, A Short History, by Augustus Muir, Fife Coal Co. Ltd., Leven, Fife, Scotland, 133 pp., 15 ills.—The growth of the company from a small group of pits at Keltly into the largest colliery concern in Scotland. The author traveled through the company's coalfields, spoke to managers and men, and spent weeks studying its archives and background. A chapter is devoted to the Charles Carlow who took over the management in 1873 and died in 1923. This company has been under public ownership since 1947. A limited number of copies of this book are available free.

The Cape Range Structure, Western Australia, Part I, Stratigraphy and Structure, by M. A. Condon, D. Johnstone, and W. J. Perry, Part II, Micropaleontology, by Irene Crespin, Bulletin No. 21, Bureau of Mineral Resources, Geology & Geophysics, 485 Bourke St., Melbourne, C. 1., Australia, free, 75 pp., 18 pl., 1953.—The area, situated on the peninsula between Exmouth Gulf and the Indian Ocean, was surveyed in 1949 by the Australian Bureau as part of the geological investigation of the Carnarvon Basin. The structure is at least 80 miles long and 20 miles wide and has a vertical closure of 1200 ft and a closed area of 1200 sq miles.

The Geology and Mineral Resources of the Brock's Creek District, Northern Territory, by C. J. Sullivan and K. W. B. Iten, Bulletin No. 12, Bureau of Mineral Resources, Geology & Geophysics, 485 Bourke St., Melbourne, C. 1., Australia, free, 52 pp., 11 pl., 11 fig., 1952.—Recent uranium activity at Rum Jungle has caused intense interest in this district.

Bibliography and Index of Literature on Uranium and Thorium and Radioactive Occurrences in the United States, Part 3, Colorado and Utah, by Margaret Cooper, Div. of Raw Materials, U. S. Atomic Energy Commission, 50¢, 589 pp., June 1954.—For geologists and laymen interested in uranium prospecting, this booklet is available from The Geological Society of America, 419 W. 117th St., New York 27, N. Y. (Part 1: Arizona, Nevada, and New Mexico, 25¢, and Part 2: California, Idaho, Montana, Oregon, Washington, and Wyoming, 25¢, are still obtainable.)

ORDER YOUR BOOKS THROUGH AIME—Address Irene K. Sharp, Book Department. Ten per cent discount given whenever possible. Order Government publications direct from the agency concerned.

Industrial Hygiene Foundation of America, Conference Transactions of 18th Annual Meeting, 1953, Transactions Bulletin No. 27, Industrial Hygiene Foundation of America, Mellon Institute, Pittsburgh. \$3.00, 183 pp., 1954.—The conference held in Pittsburgh Nov. 18, 1953 included medical, legal, joint medical-legal, engineering, and chemical-toxicological meetings. Among the papers in the engineering section is one by Theodore Hatch showing principles of plant design application in a new plant built by the Mutual Chemical Co. of America, Baltimore, and a paper by H. Rozovsky dealing with dust control improvements made in the Jeffrey mine, Asbestos, Que.

Introduction to Mining, by Bohuslav Stoces, Lange, Maxwell & Springer Ltd., London, available in the U.S. from the British Book Center, \$10.00, 2 volumes: Vol. I Text, 710 pp., Vol. II Illustrations, 368 pp., first English edition, 1954.—By the author of *Atlas of Mining Methods, Dust in Mines*, and co-author of *Structural Geology*. Edward Wisser, professor of mineral exploration, University of California, Berkeley, read this book in a manuscript translation of the original Czech edition. In the foreword to this edition, Mr. Wisser writes of his interest and excitement in discovering that: "Here at last was an exposition of the principles of mining on a level consonant with the spirit and aims of a university, rather than those of a trade school."

Horizon Mining, by C. H. Fritzsche and E. L. J. Potts, George Allen & Unwin Ltd., London, available in U. S. through Macmillan Co., \$17.00, 614 pp., with more than 400 ills. and two anaglyph diagrams, 1954.—Mr. Fritzsche, professor of mining at Technical University, Aachen, and Mr. Potts, professor of mining, King's College, University of Durham, have closely studied Continental and British coalfields and mining methods. Their book deals with all aspects of the underground planning and development of a mine on the horizon and semihorizon mining systems. The compilation of data for this book was initiated by the British National Coal Board and the foreword is by E. H. Browne, Director-General of Production, who says that this system "or a modification of it, is often necessary for the economical exploitation of our deeper coals."

how

MARCY MILL

leadership in mechanical performance can help you cut costs

Grinding mills are selected on the basis of low-cost-per-ton output resulting from efficient, dependable mechanical and metallurgical performance. That's why so many successful mining companies throughout the world continue to order and reorder Marcy® Grate Discharge Ball Mills and Marcy Open End Rod Mills.

for example...



Pouring 25,000 lb. Meehanite heads for 10'x12' Marcy Ball Mill, in Mine and Smelter foundry.



Typical group of Meehanite parts used on Marcy Ball and Rod Mills.

... MEEHANITE-METAL PARTS

Meehanite is a copyrighted trade name for a closely controlled iron, molded to rigid physical properties for uniform structure and strength, combined with good machinability. Meehanite metal is used in the construction of Marcy Mill heads, spur gears, bearings, and other castings. It has been selected for these uses since it is possible to have definite pre-determined and uniform properties for each application. Such properties may be varied to meet certain conditions and may be reproduced at any time without variation. Meehanite, due to its uniform density, high tensile strength, fatigue strength, rigidity and impact strength, provides qualities of toughness and resilience.

The use of Meehanite Metal is just one of the many Marcy Mill features which assure long, trouble-free operation and minimum maintenance... and which result in low-cost-per-ton production.

*Both Marcy and Meehanite are registered trademarks.

Licensed Manufacturers and Sales Representatives:
Canadian Vickers, Ltd., Montreal, Canada
The Austral Otis Eng. Co., Ltd., So. Melbourne, Austr.
Morgardshammers Mek. Verkskads Aktiebolag,
Morgardshammar, Sweden
Pegson Limited (for England & Africa) Coalville,
Leicestershire, England

Sales Agents:

W. R. Judson, Santiago, Chile
The Edward J. Nell Co., Manila, P. I.
The Ore & Chemical Corporation, 80 Broad Street,
New York City 4, New York
Representatives for Continental Europe

WRITE FOR CATALOG

The Mine & Smelter Supply Co.

Denver 17, Colorado

OFFICES IN SALT LAKE CITY, EL PASO, 1775 BROADWAY, N. Y. C.

—Letters to the Editor—

Editor's Note: This letter was addressed to the Secretary, but the topic is of such wide interest that we are publishing it with Mr. Winans' permission.

A Member Returns

Thank you for your letter welcoming me back to the Institute. It occurs to me that perhaps you and the Institute as a whole might be interested in why I dropped my membership for so many years and then returned.

I dropped out originally because I couldn't see where the Institute was doing me any good in the daily business of making a living. Outside of the publication of technical papers it seemed to ignore the needs of the mining engineer for an effective organization.

I have rejoined the Institute because I have come to realize that it is the only organization that is making even a halfhearted attempt to do something for the engineers in the industry and it can't do anything without our support. The Institute is doing the mining industry a great service in providing a library

of technical information but the greatest service it could perform is to promote salaries and conditions in the industry which would attract and keep trained professional engineers in the industry.

The following are a few of the things I think the Institute should take an active interest in:

1. **Wages and Salaries**—There should be a standing committee in the national and in the local sections to campaign for and negotiate better salaries and conditions. Most of us in the Western mining industry from engineer up through general superintendent and often manager have been receiving less per month than the contract miners we supervise.

2. **Jurisdiction**—We should do everything possible to claim certain positions for engineers. The engineer needs protection from the competition of tradesmen for the minor positions, and the members of other professions, notably accounting and law for the top positions in the industry.

3. **Public Relations**—We should carry on an active campaign to acquaint the general public and the mining investor with the services offered and the abilities of the professional mining engineer. All too often he is pictured as a man with considerable technical training and no practical experience. The small mine operators are especially in need of qualified engineers and for the most part don't realize it.

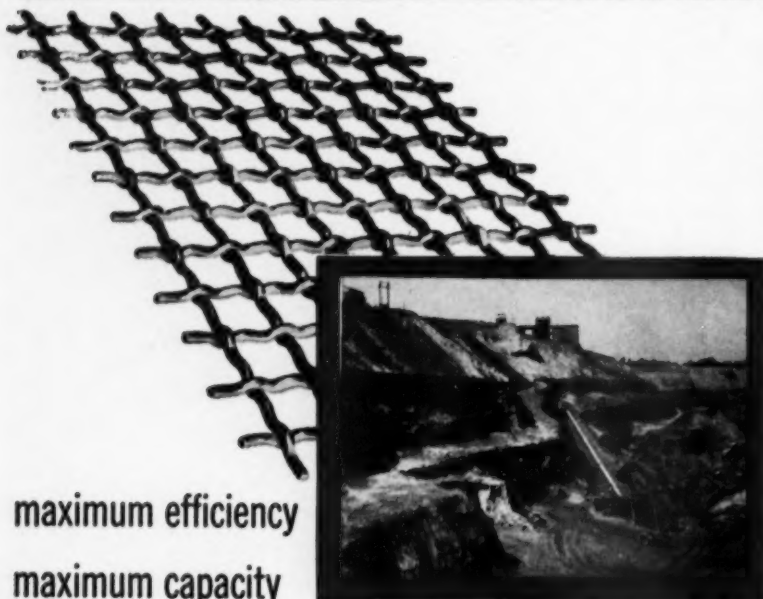
G. D. WINANS

Secretary's Reply

We, of course, welcome Mr. Winans back into the fold and will do everything we can practically do to make his membership worth while. The matters he mentions are typical of those on which the national engineering societies can best take joint action. Wages and salaries, top positions held, and public relations are topics of equal interest to all types of professional engineers.

Salaries of professional engineers, we believe, are now much more equitable than they were a generation ago. Their job security is also considerably greater. Too, engineers are holding more of the top positions than formerly. A recent Columbia University survey showed that 40 pct of industrial management is now engineer-trained, replacing both the lawyer and banker in top industrial posts. More and more recognition is being given to engineers. President Eisenhower named two AIME members for posts in his cabinet.

The AIME, together with the civil, mechanical, electrical, and chemical engineering societies, is promoting the interests of engineers as a group through the Engineers Joint Council and the Engineers Council for Professional Development. Both of these Councils have many active committees promoting the very things Mr. Winans mentions.



maximum efficiency

maximum capacity

maximum life . . . all yours with

CAL-WIC Industrial Screens

You can always select the right screens with the correct mesh and metal for your job from CAL-WIC's extensive line of industrial screens. CAL-WIC Industrial Screens are fabricated in a wide range of types from the toughest carbon and alloy steels. Whether for process-

ing, cleaning, grading, screening, for any type of equipment, CAL-WIC Industrial Screens will give the results you require.

CAL-WIC engineering assistance is available to help you solve your screening problems—write, today.

CAL-WIC
INDUSTRIAL SCREENS (CI)
THE COLORADO FUEL AND IRON CORPORATION

2611

Albuquerque • Amarillo • Billings • Boise • Butte • Casper • Denver • El Paso • Ft. Worth
Houston • Lincoln (Neb.) • Los Angeles • Oakland • Oklahoma City • Phoenix • Portland
Pueblo • Salt Lake City • San Antonio • San Francisco • Seattle • Spokane • Wichita
CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Montreal



JEFFREY new 6F AERODYNE FANS combine economy and efficiency

For light and medium-duty mine ventilation up to 5" W.G. pressure, Jeffrey now offers the new, economical 6F Series AERODYNE Fan.

The 6F Series combines low cost with high efficiency. Many of the fine engineering features of the AERODYNE Series first introduced by Jeffrey in 1936 are incorporated in this new self-contained 6F Fan.

THESE FEATURES IMPROVE OPERATION:

- ♣ Universally adjustable blades made of cast-aluminum alloy and mounted on a solid aluminum alloy hub.
- ♣ Air reversal possible by reversing blade pitch or direction of rotation.
- ♣ Flange-mounted anti-friction bearings.
- ♣ Various lengths of expansion discharge for different duties.
- ♣ Overhung drive and fan wheel for belt drive up to 125 HP ... can be direct-connected for higher HP ratings.

Learn more about the 6F Series — the fan with AERODYNE quality in the low cost field. Write to the Jeffrey Ventilation Division for details.



THE JEFFREY

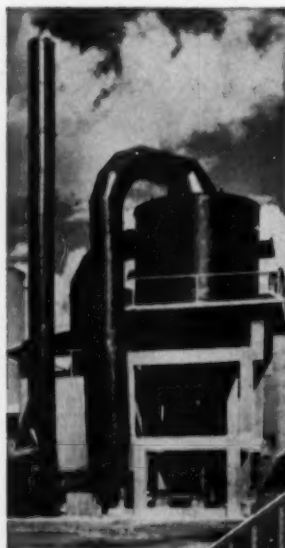
**IF IT'S MINED, PROCESSED OR MOVED
... IT'S A JOB FOR JEFFREY!**

ESTABLISHED 1877
MANUFACTURING CO.
Columbus 16, Ohio
*sales offices and distributors
in principal cities*
PLANTS IN CANADA, ENGLAND, SOUTH AFRICA.

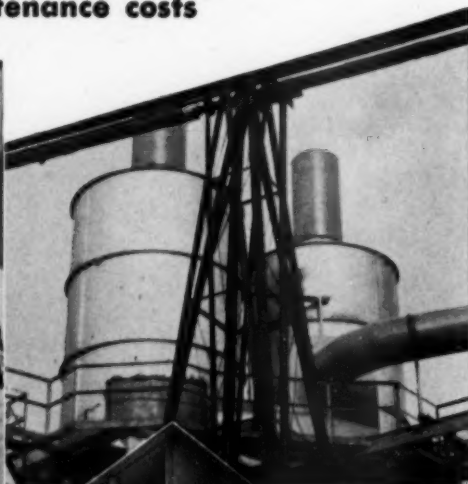
Norblo

Dust and Fume Collection Systems

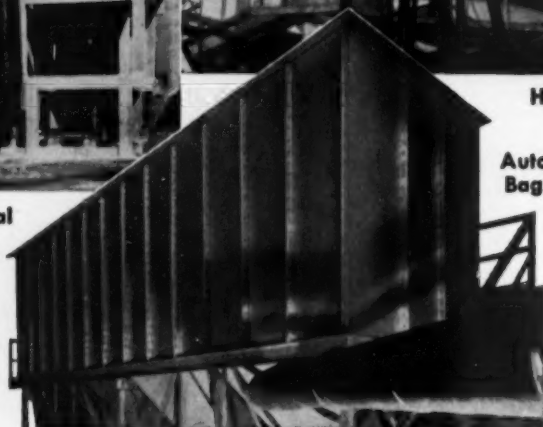
make outstanding records for high recovery with low operating and maintenance costs



Centrifugal



Hydraulic



Automatic Bag Type

These three important types of Norblo collecting systems, frequently used in certain combinations, bring you economical, dependable control as required in a wide range of industries. "Guaranteed Efficiency" is not an empty phrase at Norblo. We stand back of every installation that's used for the purpose and at the capacity for which we designed it. All component parts are made by Norblo, under controlled specifications.

For more than 40 years Norblo has engineered and supplied installations of every size in the rock products, smelting, chemical, metal working, milling and processing fields. It pays you to get the facts about Norblo Dust and Fume Collecting Systems. Give us a description of your problems.

The Northern Blower Company

Engineered Dust Collection Systems for All Industries

6424 Barberton Ave. Olympic 1-1300 Cleveland 2, Ohio

Meet The Authors

T. H. Janes (p. 1010) is an engineer with the Industrial Minerals Div., Mines Branch, Dept. of Mines & Technical Surveys, Ottawa. While this is his first paper for the AIME, another on sulphur and pyrites in Canada was published by the Canadian Institute of Mining and Metallurgy in 1952. Mr. Janes holds a B.S. in mining engineering from Queens University conferred in 1938. He is a past chairman of the CIM's Industrial Mineral Div. Mr. Janes has been with International Nickel Co., Kerr-Addison Gold Mines Ltd., and Defense Industries Ltd. Hobbies include gardening, woodworking, bridge, and poker. Mr. Janes also has a spectator interest in sports.



W. A. BOYER

W. A. Boyer (p. 989) was born in Bennington, Kan. He earned his B.S. in electrical engineering at Montana State College. While at school he was elected to Phi Kappa Phi and Tau Beta Phi and was president of Lambda Phi which later went into Pi Kappa Alpha. Mr. Boyer was associated with General Electric Co., Anaconda Copper Mining Co., and Federal Mine & Smelting Co., before his present position as superintendent of mechanical and electrical depts. of American Smelting & Refining Co. Most of his time has been spent with design, installation, and maintenance of electric mine hoists. Fishing, golf, color photography, and collection and preservation of historical artifacts are among Mr. Boyer's hobbies.

J. Visman (p. 1015) preparation engineer with the Dept. of Mines & Technical Surveys, Calgary, Alberta, came to Canada in 1951 from the Netherlands. He is in charge of the Fuels Div. laboratory, and previously worked for the Dutch State Mines, mainly in the field of coal preparation research. During World War II, Mr. Visman served with the U. S. and British Armies, gaining the rank of first lieutenant. He fought in Holland during that country's liberation in 1944 to 1945. He has been the author of some 13 papers. Sailing and fishing take up his free time.

an EXTRA MARGIN of Strength



without Excess Weight

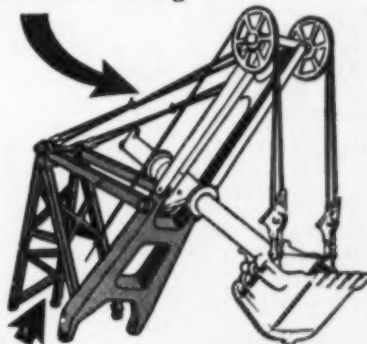
The unique two-section boom used on Bucyrus-Erie $4\frac{1}{2}$ - to 8-cu. yd. Ward Leonard electric shovels solves one of the problems of front-end construction on heavy-duty excavators in a sound, practical way. It provides the strength needed to withstand the shock loads of digging, yet is remarkably light in weight to help keep swing inertia low.

The two-section boom is only one example of that extra margin built into Bucyrus-Erie heavy-duty excavators—an extra margin in design that pays off in extra loads and more output. There's much more to the story—the tubular dipper handle, the independent rope crowd, the twin dual hoist ropes, the deck location of crowd machinery, the improved dipper design. Write for complete information on the model of your choice—the $4\frac{1}{2}$ -yd. 110-B, the 6-yd. 150-B, and the 8-yd. 190-B.

**BUCYRUS
ERIE**

SOUTH MILWAUKEE, WISCONSIN

Upper boom section, bridge-strand connected to the A-frame, is relatively lighter in construction, because it has to carry only the loads resulting from the pull of the hoist ropes and from the acceleration and deceleration of the swing.



Sturdy lower section, securely attached to the A-frame by pin-connected struts to form an integral part of the machine, has ample strength to take the stresses and shock loads of the digging cycle. Widespread boom feet provide a brace effect to take swing loads . . . no cable suspension or sway braces are required.

Manufacturers News

New Products

• FILL OUT THE POSTCARD FOR MORE INFORMATION •

Equipment

Geophysical Instrument

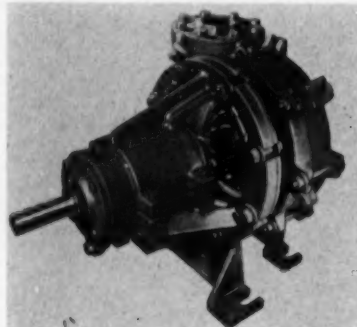
High resolution seismograph announced by *Houston Technical Laboratories* is designed for extremely shallow reflection work in the depth range of 100 to 2500 ft. Model HR system components differ from ordinary reflection seismographs in



higher frequency response, higher paper speed, and higher resolution, making possible accurate resolving of reflections from depths as shallow as 100 ft. Utmost portability and flexibility in field use are other features. **Circle No. 1**

Pump

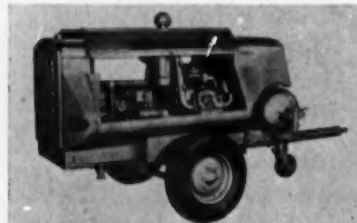
Rubber-lined pump in new design from *Allis-Chalmers* handles abrasive material of $\frac{1}{8}$ -in. to 325 mesh



size. Open and closed impeller models have been designed for capacities from 10 to 3000 gpm, and heads to 140 ft. **Circle No. 2**

Portable Compressor

Two-wheel portable introduced by *Gardner-Denver* has 125 cfm output from two-stage water-cooled compressor with either gasoline or diesel drive. Compressor is W-type, similar



to other GD portables, and has water cooling and controlled water circulation for warm up prior to engaging the clutch drive. **Circle No. 3**

Engineers Tools

Two handy gadgets speed everyday tasks. *Pickett & Eckel Inc.* markets a unique slide rule with a conversion scale (to eliminate tables of equivalents) and a complete trig scale arrangement. **Circle No. 4**. For those who buy lumber in quantities a new pocket size rule from *Lumtape Corp.* reads directly in board feet. **Circle No. 5**.

Optical Transit

Model T-1 Optical repeating transit distributed in U.S. by *Wild Heerbrugg Instruments Inc.* is one of a



line of Swiss-made precision transits. Completely enclosed, operated entirely from behind, and with internal illumination of circles that are read in the micrometer alongside the telescope eyepiece, the unit has aroused considerable interest in the mining industry. **Circle No. 6**

News and Notes

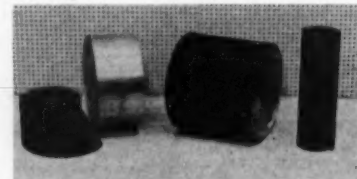
Soilttest Inc. has named M. D. Morris as New York representative . . . *Maquinaria Minera e Industrial S.A.*, Mexico City, headed by Stanley M. Moos, is now exclusive agent for *National Filter Media Corp.* in Mexico and Central America . . . *Gardner-Denver Co.* recently moved into its new 17,000-sq ft unit fabrication and warehouse building in Dallas . . . *H. K. Porter Co. Inc.* announced acquisition of *Pioneer Rubber Mills Inc.* of Pittsburg, Calif., which becomes part of *Quaker Rubber Corp.*, one of Porter's nine divisions . . . *Copco Eastern Ltd.* moved its office and warehouse from Ironwood, Mich., to new quarters at 1720 West Superior St. in Duluth . . . *Allis-Chalmers Tractor Div.* issued a booklet describing facilities for groups of individuals visiting the Springfield, Ill., Works as guests of industrial dealers.

Radiation Detector

The Bismuth Nuclimeter is claimed to be the most sensitive portable radiation detector made. *Detectron Corp.* also stresses ruggedness and compactness in instrument that gets full scale reading at 0.005 MR hr. **Circle No. 7**

Pulley Lugging

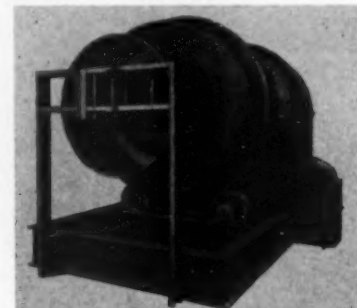
Minnesota Mining & Mfg. Co. has developed a Safety-Walk brand,



waterproof, nonslip surfacing, thin and flexible enough to be adapted to any industrial pulley. **Circle No. 8**

Scrubber

McLanahan & Stone Corp.'s Hi-Speed scrubber revolves at speeds sufficient to cause material to be re-



tained by centrifugal force on lifting shelves to the top of the cylinder. Material then cascades upon itself to break down softer material and to free clay and loam. **Circle No. 9**

Loader

Smaller companies and contractors who need one piece of machinery to handle variety of earthmoving jobs will be interested in the Drott 4-in-1 hydraulic controlled attachment for



International Harvester's TD-6 crawler tractors. Unit converts to bullclam shovel, bulldozer, front-end loader, or clamshell. **Circle No. 10**

Free Literature

(21) **PROCESS INDUSTRIES:** General Electric's 28-page "Electric Equipment for the Process Industries" provides detailed information on: GE electric equipment for power generation; power distribution and conversion; power utilization; instrumentation; descriptive publications; and GE service shops and warehouses, applicable to the process industries.

(22) **MAGNETIC SEPARATION:** Catalog 602-4 from Magnetic Engineering & Mfg. Co. presents MEMCO's line of electro and permanent magnetic pulley type separators. Machines are made in stationary or portable styles, horizontal or inclined, open or fully enclosed, depending on requirements.

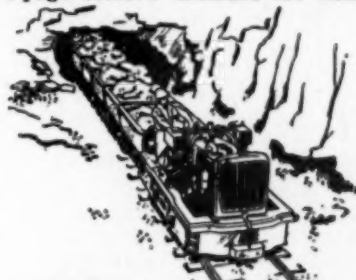
(23) **BLAST HOLES:** Spang & Co.'s "Churn Drill Tools for Blast Holes" covers heat treated blast hole bits and drilling stems, weldless drilling and fishing jars, replacement blade sections, valve bailers. Also given are helpful hints and the proper procedure for dressing and hardening cable tool bits.

(24) **LIGHTWEIGHT CONCRETE:** Construction and lightweight insulation problems? National-Crete, a cellular concrete, can be precast in intricate shapes, poured in place, nailed, or sawed. National Foam System's equipment is said to be easily operated by unskilled workers.

(25) **GRAVITY METER:** Houston Technical Laboratories bulletin describes the Worden gravity meter, which weighs 5½ lb and requires no external power source. Accuracy, dependability, and low weight are due to the use of a vacuum-sealed, self-compensating element made of nonmagnetic quartz with near perfect elasticity.

(26) **CORE DRILLING:** Two-color, 8-page bulletin from Sprague & Henwood Inc. contains new information on the model 142 core drilling machine. Besides a detailed illustrated description of this high speed, heavy duty machine, together with complete specifications and working data, bulletin 160 lists the many items of accessory equipment required for successful diamond core drilling.

(27) **UNDERGROUND MINING:** The right combination in mining equipment, dependability, economy of operation, and long life is the topic of Caterpillar Tractor Co.'s 8-page booklet. Included are testi-



monials by mine owners and superintendents, and several action pictures of track-type tractors, shovels, bulldozers, motor graders, wheel tractors, and engines operating in the U.S. and Canada.

(28) **PORTABLE DRILL RIGS:** For fast seismograph shot hole, blast hole, water well, or core drilling, Damco introduces the AR-1250 and AR-2000. Special features include: hydraulic torque coupling and transmission, air clutches requiring no adjustment, flush decking, and high speed table rotation that can be obtained for diamond coring at no additional cost.

(29) **TRACK CLEANING:** Following the success of the 40-in. track cleaner, American Mine Door Co. has designed the 30-in. track cleaning machine for thinner coal seams. Bulletin lists features, specifications, savings gained, and explains how "spillage recovered often pays the purchase price in a matter of months."

(30) **CONVEYOR BELTS:** Proper belt selection is the "Key to More Profitable Belt Conveyor Operation." Hewitt-Robins bulletin describes facilities of the "only firm in existence which designs, engineers, and manufactures all essential equipment for a complete belt conveyor—including the belt."

(31) **MATERIALS HANDLING:** Various types of equipment and structures for handling coal, ore, and other bulk materials are described in Dravo Corp.'s 32-page illustrated booklet. Discussed are mechanical, electrical, and structural features of such equipment as ore and coal bridges, man trolley unloaders, rope-operated towers, and rail clamps.

(32) **ROOF BOLTING DRILL:** Goodman Mfg. Co.'s catalog 5410 describes "the world's only dust-free dry rock drill" designed for drilling a clean hole in a roof. It uses no water and cannot drill unless dust is being removed. Holman Dryductor extracts dry dust as it is made, passes it through the rock drill and draws it by pipe line to a container away from the drill and face crew.

(33) **INDUSTRIAL HYGIENE:** Available from Industrial Hygiene Foundation, Mellon Institute, are two papers: "Environmental Medicine in Industry," by C. Richard Walmer, and "Principles of New Plant Design for Health Protection," by Theodore Hatch.



MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.



Mining Engineering

29 West 39th St.

New York 18, N. Y.

Not good after January 15, 1955 — if mailed in U. S. or Canada

Please send me { More Information ☐ Price Data ☐ Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	Students are requested to write direct to the manufacturer.								

Name _____ Title _____

Company _____

Street _____

City and Zone _____ State _____

(34) RUBBER-LINED PUMPS: *Allis-Chalmers* bulletin describes improved rubber-lined pumps for handling abrasive, fine size material— $\frac{1}{2}$ in. to 325 mesh—sand, taconite, grinding mill discharge, tailings, silicon carbide, etc. Type NRL are available in open or closed impeller models at capacities from 10 to 3000 gpm at heads through 140 ft.

(35) NICKEL ALLOY STEELS: *International Nickel Co.* has a 36-page bulletin, "The Tensile and Impact Properties of Quenched and Tempered Nickel Alloy Steels in Different Sizes." Over 70 charts show mechanical properties that may be expected in various sizes.

(36) RADIOACTIVITY SURVEYS: *Nuclear Instrument & Chemical Corp.*'s brochure describes "field-proven" scintillation counting equipment and how it is used, mounted in an automobile or airplane, for uranium or oil prospecting.

(37) HAND TORCHES: *Air Reduction Sales Co.*'s 36-page catalog covers a complete line of torches and tips for oxyacetylene cutting and welding. Every Airco standard torch and tip is listed as well as necessary accessories.

(38) LABORATORY APPLIANCES: Published by *Fisher Scientific Co.*, "The Laboratory" is devoted to latest developments in laboratory instrumentation and technique. Feature article in current issue describes work of the U.S. Treasury chemists.

(39) EDUCATION BY MAIL: "The Training Job and How to Meet It," from the Cooperative Training Div., *International Correspondence Schools*, appraises various ways correspondence education can be adapted to meet training problems on either an individual or group basis. Outlines of typical courses in use by more than 4500 companies in the U. S. and Canada are included.

(40) GASKET SEALABILITY: Latest in "The Gasket" series of technical bulletins from *Johns-Manville* is "How Flange Surface Finishes Affect Gasket Sealability and Joint Performance," by John W. Axelson and Heber H. Dunkle. Booklet provides for selection of most suitable flange surface for a given gasket.

(41) COMPRESSOR TROUBLE? Locating trouble in vertical water-cooled air compressors is subject of a new "Trouble Savers" issued by *Worthington Corp.* Bulletin is de-



signed to help operators of YC and DYC compressors detect existing troubles and be alert to ways in which trouble can be prevented.

(42) HARD-FACING: *Mir-O-Col Alloy Co.*'s 72-page brochure on hard-facing includes recommendations of specific hard-facing rods for over a thousand pieces of equipment subject to impact and abrasion.

(43) BATTERY CHARGING: *Motor Generator Corp.*'s data sheet MGC-114 on single and multiple-circuit motor generators for industrial and mine locomotive batteries describes fully automatic operation and modified-constant-potential charging for maximum battery protection.

(44) POWER TRANSMISSION: *American Pulley Co.*'s latest bulletin covers its complete line of power-transmission equipment such as: Wedgbelt drives, Shaft-King Speed-Reduction drives, adjustable speed sheaves, and Hi-Torque pulleys.

(45) COLLOIDS: *Acheson Colloids Co.*'s bulletin No. 460 tells how 'dag' colloidal dispersions serve industry in a wide range of uses—lubrication to cancer research. Listed are 40 basic dispersions of graphite, molybdenum, disulphide, vermiculite, and zinc oxide in various carriers.

(46) MAGNETIC-PARTICLE TESTER: Bulletin from Research & Control Instruments Div., *North American Philips Co.* explains the operation of a new portable magnetic-particle test unit. Data covers use of Portaflux for field checking steel and iron objects for surface cracks or discontinuities.

(47) GEAR DRIVES: *Falk Corp.* bulletin has selection tables, dimensions, weights, overhung load ratings, and thrust capacity ratings needed to select horizontal, vertical, or right angle Motoreducers in either All-Motor or Integral design. Applications are illustrated.

(48) ORINOCO PROJECT: Published by *Link-Belt Co.*, "The Orinoco Project," tells the story of "one of the great frontier epics of modern industrial history," the development of Orinoco Mining Co.'s rich Venezuelan iron ore deposit. An excellent presentation, with drawings, maps, and photographs.

(49) LABORATORY EQUIPMENT: Bulletin 1153 from *Soiltest Inc.* covers Blue M electric ovens, furnaces, and related equipment. Among machines illustrated are: Ultra-Temp oven for temperatures up to 649°C., Lab-Heat muffle furnace, and Blue M Magni-Whirl utility water bath.

(50) ONE-USE DETACHABLE BITS: For bulletin RD-29 from *Cleveland Rock Drill Div., Le Roi Co.*, see page 945.

(51) SINTERING MACHINES: For detailed information on *Dwight-Lloyd* sintering machines. See page 948.

(52) DIESELS: For "The Inside Story" from *Detroit Diesel Engine of General Motors Corp.* on GM series 71 diesel engines, see page 949.

(53) URANIUM PROSPECTING: For catalog from *Precision Radiation Instruments Inc.* on instruments for detecting uranium and other metals. See page 942.

(54) BELT CONVEYOR CARRIERS: For bulletin 453 on *Stephens-Adamson Mfg. Co.*'s "SIMPLEX" carriers. See page 1025.

(55) DIAMOND CORE DRILL: For *Joy Mfg. Co.*'s bulletin D-28 on the Joy 22-HD, see page 964. For bulletin D-21 on the Joy 12-B circle 56.

FIRST CLASS
PERMIT No. 6433
Sec. 34.9 P.L.&R.
New York, N. Y.

BUSINESS REPLY CARD

NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

3c.—POSTAGE WILL BE PAID BY—

MINING ENGINEERING

29 WEST 39th STREET

NEW YORK 18, N. Y.

THE DORR CO., Stamford, Conn., and OLIVER UNITED FILTERS INC., Oakland, Calif., announced execution of an agreement for merging the two companies. The merger becomes effective Dec. 31, 1954. Name of the new company will be Dorr-Oliver Inc. with headquarters in Stamford. Officers of the merged companies will be: Edwin Letts Oliver, founder-chairman of the board; John V. N. Dorr, founder-chairman of the board; J. Delano Hitch, Jr., president; Edwin Letts Oliver, Jr., administrative vice president; Douglas C. Reybold, administrative vice president; William Harold Oliver, vice president; T. Bartow Ford, vice president; Lloyd R. Boling, vice president; Arthur Terry, Jr., vice president; and G. H. Dorr, II, secretary and treasurer.

Construction work on various mill programs of Falconbridge Nickel Mines Ltd. is in danger of serious lagging unless equipment deliveries are speeded up. However, the underground program is reported going ahead well. Falconbridge, in its recent semiannual report, noted that half year profit was \$974,619 as against \$1,815,288 for the same period last year.

ILLINOIS ZINC CO. has obtained options to buy a controlling interest in Columbium Corp., a firm with a 50,000 acre concession in British Guiana believed to contain columbium and tantalum ore. It was also announced that Illinois Zinc is negotiating with Defense Minerals Exploration Administration for an exploration contract at the Shannon mine, Gleeson, Ariz., a former copper producer. Illinois Zinc is developing the mine as a lead-zinc producer.

Bunker Hill & Sullivan Mining & Concentrating Co.'s \$3 million improvement and modernization at its Kellogg, Idaho, lead smelter is almost completed. The new 202-ft smokestack has been placed in operation. The old stack will be removed in the near future.

LITHIUM CORP. OF AMERICA INC. announced purchase of 36 claims in the Cat Lake area of Manitoba. It was also stated that the plant expansion at Bessemer City, N. C., was proceeding on schedule. No equity financing is involved in the \$7 million project. Mining operations have started and the plant will be in production by Jan. 1, 1955. In addition to ore reserves at Kings Moun-

tain, N. C., the report stated, the company has entered into a contract with Quebec Lithium Corp. to buy the entire output of spodumene concentrates produced at its new Canadian plant. Quebec Lithium is a subsidiary of Sullivan Consolidated Mines Ltd. of Canada.

Philadelphia & Reading Coal & Iron Co. has arranged with Hydrocarbon Research Inc. for a long-range experimental program in coal gasification using anthracite. Hydrocarbon will carry on work in its Trenton laboratories. Philadelphia & Reading has carried on evaluation studies and applied research work in the gasification field for several years.

CORE DRILLING HAS STARTED on Shasta Lake iron ore deposits near Redding, Calif. Drilling to determine the extent of the orebodies is being done by G. I. Dumond, holder of options in the area. Morrison-Knudsen Co. Inc., Boise, Idaho, is aiding in the drilling. Bert C. Austin, president of Idaho-Maryland Mines Inc., is consulting engineer. Operating under the name of Mt. Shasta Steel & Tube Co., Mr. Dumond envisions a steel mill 10 miles north of Redding should the deposits prove up to expectations. U. S. Bureau of Mines drill holes in 1944 revealed reserves of about 4.68 million tons averaging 37.8 pct iron.

A campaign to prevent injuries and deaths from falling ground in mines will be launched by the Mining Section of the National Safety Council. The council reports that falling ground causes some 1100 injuries and deaths in the U. S. each year. The drive is scheduled to start January 1 and terminate Dec. 31, 1955. Any underground mine, excluding coal, may participate providing 25 or more employees work underground.

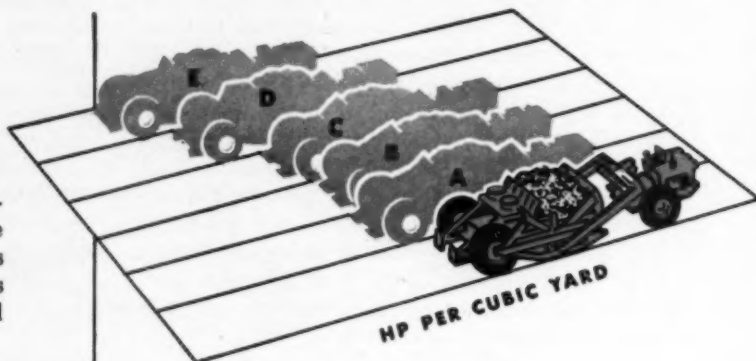
ATLAS CORP. made one of the largest investments in its portfolio by purchasing the uranium mine and claims of V. J. Pick, former Minneapolis electrical contractor who discovered the mine in 1952. Floyd B. Odum, Atlas president, announced the purchase price of \$9 million. The mine is the third purchase made by Atlas of uranium property this year. Mr. Pick stated that the mine had known reserves of uranium ore valued at \$12 million. Total value, on a conservative basis, including unproven reserves, was pegged at \$25 million by Mr. Pick. Current mining, Mr. Pick said, is grossing about \$50,000 per month. A mill may be built near the mine, Mr. Odum said.

COMPARE POWER, BALANCE AND TRACTION AND

Why Allis-Chalmers Motor Scrapers

Examine the Allis-Chalmers TS-200 or TS-300 Motor Scraper point by point, feature by feature. Then let your Allis-Chalmers dealer demonstrate what these features mean to you in terms of bonus yardage and dependable performance.

See how fast Allis-Chalmers Motor Scrapers accelerate to "get the jump" on normal production from the moment they leave the pusher. See how safely they high-ball with a full load . . . how fast and steady they pull through the deep fill and return, up grade, to start a new cycle. Compare these Motor Scrapers on the basis of work done per dollar of investment. We think you'll agree an Allis-Chalmers Motor Scraper is your *number one* earth-moving value.



ACCELERATES FAST

The TS-200 develops 17.6 hp per cu yd struck capacity . . . the TS-300 develops 20 — the highest ratios in their respective classes. With more power to move the payload, these machines get away from the pusher *fast* and maintain high average speeds throughout the entire cycle.



PERFORMANCE MAKES DOLLARS WHEN DESIGN

YOU'LL SEE

Out-produce

WEIGHT DISTRIBUTION LOADED



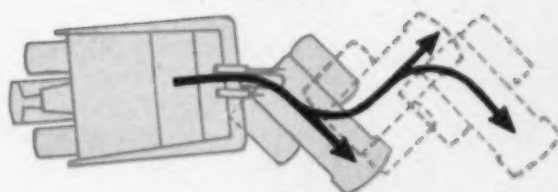
HIGHBALLS WITH THE PAYLOAD SAFELY

Loaded, the Allis-Chalmers Motor Scraper has equal weight on all four tires. This ideal weight distribution, together with low center of gravity, direct hydraulic steering which eliminates jack-knifing, and big air brakes on all four wheels, allows the Allis-Chalmers Motor Scraper to take advantage of its high hp ratios by maintaining fast, yet safe haul speeds.

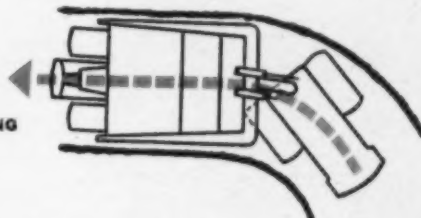


MAKES SENSE

DUCK-WALKING



BACKING



MANEUVERS EASILY

There are no steering brakes to rob you of tractive power. Instead, direct hydraulic rams turn the tractor in the desired direction of travel. Steering is sure and positive—even going down extremely steep slopes in loose footing.

By swinging tractor left and right with the steering rams, the Allis-Chalmers Motor Scraper can duck-walk through heavy going where others bog down.

Backing up in close quarters is simple. Two-wheel tractor has complete control over scraper body . . . can even change directions without forward or backward movement.

WEIGHT DISTRIBUTION EMPTY



COMPLETES THE ROUND TRIP QUICKLY

The return trip from the fill is usually uphill. That's where two-wheel design pays off. When empty, 66 percent of the Motor Scraper's weight is carried on the traction wheels. There are no front wheels to rob drive wheels of tractive weight or to create rolling resistance in heavy going. This enables the Motor Scraper to make the round trip faster and usually in higher gear than other units.

ALLIS-CHALMERS
TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

Proven PERFORMANCE

$\frac{7}{8}$ " HEXAGON

SANDVIK COROMANT drill steels

Throughout the entire world Coromant tungsten carbide tipped integral drill steels have proved their right to leadership. Consistent uniformity—lower cost per foot of hole drilled, freedom from connection troubles, longer drilling life and Copco on-the-job service—these things have made them the only logical choice wherever drilling costs are most closely watched.

Behind all this stands a program of continuous research and field tests aimed at providing the finest steels that metallurgy and engineering skill can produce.

Coromant integral steels are carried in stock at all Copco branches ready for immediate shipment. We stand four square behind our policy that no job shall be held up for lack of Copco equipment.

FLEXIBLE

- Coromant tungsten carbide tipped steels are guaranteed.
- They will not stick in drill holes.
- Chisel-type cutting edge gives high penetration speed.
- Specifically designed for jacking pusher type drills.
- Quick and easy sharpening of working face.
- No connection problems—requires no steel chop.
- All Copco prices are published and guaranteed.

$\frac{3}{4}$ " HEXAGON



ROCK DRILLS
DRILL STEELS
COMPRESSORS
AIR TOOLS



EASTERN Ltd.
151 Linwood Avenue—Paterson 2, N.J.
PACIFIC Ltd.
930 Brittan Avenue—San Carlos, Calif.
MEXICANA S. A.
Ave Juarez y Calle Comanfort
Torreon, Coahuila, Mexico
Canadian Copco Ltd., Metropolitan
Boulevard, Montreal A.M.F., Que.

BRANCH OFFICES AND WAREHOUSES THROUGHOUT NORTH AMERICA

Utah Uranium Boom Still Shows Strength

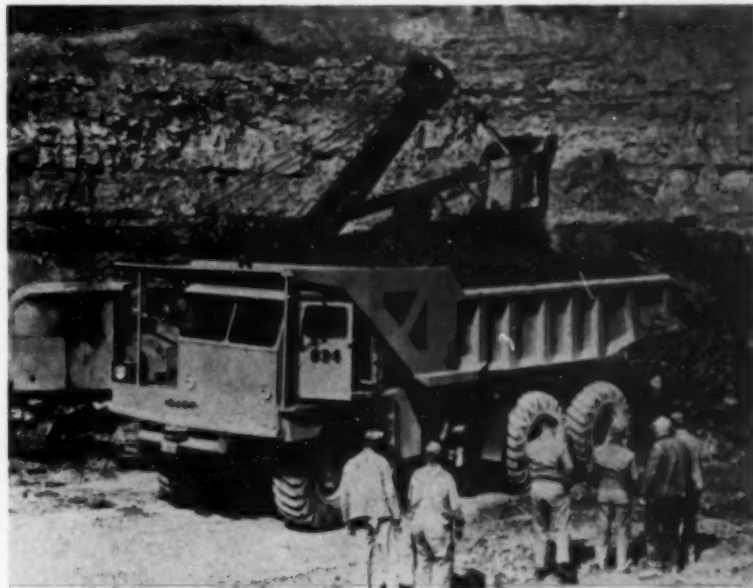
The Utah uranium boom goes rolling along, with more than \$12 million worth of stock sold in the last few months. The State Securities Commission received applications from 112 companies requesting permission to sell stock to finance Utah uranium development.

The agency denied four applications and at last report had 31 still under study. The remainder have been approved. Uranium stock sales hit a feverish peak last June but still goes on at a steady pace. In early summer, stock offerings were often oversubscribed before they were issued. Recently, the buying public has practiced more selection.

According to Milton H. Love, director of the State Securities Commission, "All of those who bought stock or filed claims aren't going to get their money back. But I think at least 20 pct of the claims will prove profitable."

New Leaching Plant At Riverton Facility

Manganese Chemicals Corp. marked the end of the second construction phase at its Riverton, Minn., plant with completion of a new leaching system. Manganese Chemicals is reported to be the first company to successfully extract

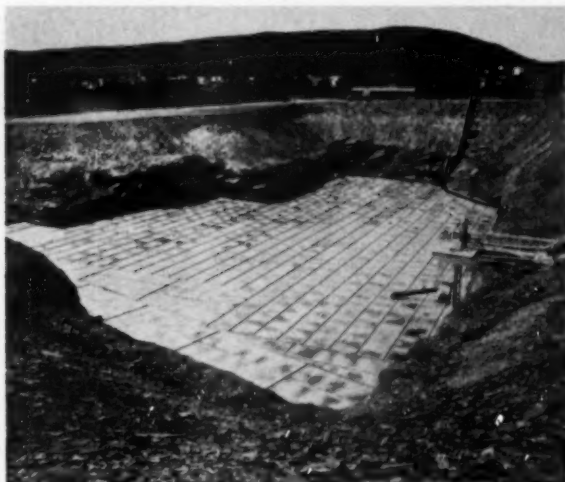


This one of two giant 50-ton dump trucks now in use on the Mesabi range. Bodies and hydraulic hoists were designed and built by Marion Metal Products Co., Marion, Ohio. The Marion dump body units were purchased by the Dart Trucking Co., Kansas City, and mounted on Dart Model 40-T trucks. Payload is 36 cu yd. Two 275-hp diesels power the trucks. Special feature is a heated floor, allowing trucks to work in temperatures as low as -60°F .

highly pure manganese from low grade ores on the Cuyuna range of northern Minnesota.

Pilot plant runs in the company's research and control laboratory

proved successful. Processing of commercial quantities of MnCO_3 and MnO_2 started September. The plant is designed to handle 70,000 lb of manganese carbonate per day.



Heating oil, produced during slack summer months, will be stored in this slate quarry for shipment to distributing points in the Northeast at the peak of the heating season. Steel pontoons, weighing almost 3 tons each, form a 56,000-sq ft flexible floating roof over the quarry at Wind Gap, Pa. Esso Standard Oil Co. has delivered the first of 42 million gal from the Linden, N. J., refinery. Installation at the right delivers oil and water to the quarry. Oil level is maintained by pumping water under the oil.



International Nickel Co. is maintaining production rate of 275 million lb of nickel per year. With the intensified demand for nickel showing no signs of relaxing, Inco may be called upon to increase its efforts. According to reports, there are definite signs at the Sudbury camp that ore reserves will continue to be discovered for some time. This year's exploration investment by Inco is said to be not far behind the 1953 expenditure of \$6 million. Mine worker is shown testing roof bolts at Garson mine in Ontario.

Huge Production Visualized for New Johns-Manville Mill

Johns-Manville last month opened the largest asbestos mill in the world at Asbestos, Que. It will mill more than one third of the Free World's supply of asbestos fibre, most of which finds its way to the U. S. to be manufactured into scores of essential products for home, farm, industry, and national defense.

Anticipating the trend toward greater mechanization in the asbestos industry, the new Johns-Manville mill will replace several existing mills and provide more modern facilities with increased production capacity at lower operating costs, according to L. M. Cassidy, chairman of the board. The new mill is the latest project of the Quebec asbestos mining industry which has embarked upon a \$70 million program of ex-

pansion and development of new mines, mills, and machinery.

Dignitaries of church and state joined Johns-Manville officials in ceremonies putting the first half of the new mill into commercial production. Prime Minister Maurice L. Duplessis of Quebec gave the signal for operations to start.

Others participating in the ceremonies included A. R. Fisher, president, Johns-Manville Corp.; the Most Reverend Philip Carrington, Anglican Archbishop of Quebec; and Monsignor Georges Cabana, Roman Catholic Archbishop of Sherbrooke.

The new mill occupies a 14-story, steel and concrete building that has 22½ acres of floor space. When in full production early in 1956 it will provide additional capacity to reach

(Continued on page 964)



Automatic batching equipment is used for mixing "shorts and floats" grades of asbestos fibre. As many as five different grades of fiber can be blended in varying amounts with this equipment.

Aerial view of new mill at Canadian Johns-Manville, now half completed. The town of Asbestos is in the background along with other mining and milling facilities. In left foreground is the dry rock storage building with a 60,000 ton ore capacity. Old milling installations to be replaced are beyond storage building.



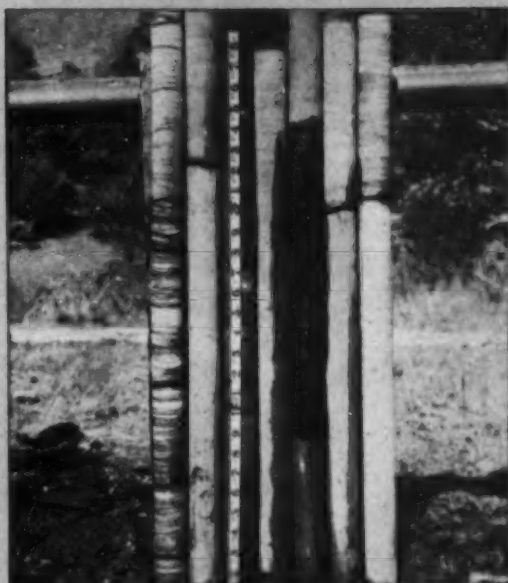
The open pit accounts for only about 28 pct of total production at the mine, with underground operations carrying the main load. The plant in the foreground is the largest in Canada devoted to the production of asbestos building and industrial products. Production capacity is about 30 carloads of finished products per day.

WANT ACCURATE CORES AT LOW COST?

On the strength of the story told by these cores, a new mine was opened and became a big producer. With a Joy Diamond Core Drill, it was a simple matter to analyze and measure these cores and determine, precisely, the mineral content, size and value of the deposit.

Prospecting can be done at a fraction of the cost and in much less time than any other method. There are many other uses for Joy Diamond Core Drills, too. They're great for blocking out ore bodies, testing sub-surface foundations and completed structures, and drilling holes for pressure grouting, underground drainage, ventilation and gas relief.

For full details on Joy Diamond Core Drills, write for bulletins to Joy Manufacturing Company, Oliver building, Pittsburgh 22, Pa. In Canada: Joy Manufacturing Company (Canada) Limited, Galt, Ontario.



... USE JOY DIAMOND CORE DRILLING EQUIPMENT



THE JOY 22-HD is a heavy-duty drill that's rugged, portable and versatile. It's direct-driven with four-speed transmission—either hydraulic or screw-feed swivelhead. An easily-operated, rugged, but sensitive hoist that handles strings of drill pipe up to 2000 feet and operates at hoisting speeds up to 290 feet per minute. Details in Bulletin D-28.



THE JOY 12-B is a highly efficient drill that can be quickly dismantled into four compact units for convenient transportation. With a capacity of 1000 feet, its versatility and portability make it ideal for the other duties required of a sturdy drill. Available on skid or column mounting for surface or underground operation. Skid mounted model uses either hydraulic or screw-feed swivelhead. Details in Bulletin D-21.

CORE DRILLING BY CONTRACT

Complete core drill contracting service by highly skilled crews is available for mineral prospecting, blocking out ore bodies, testing foundations, drilling grout holes, etc. Write for full details.

TRUCO AND JOY-TRUCO
DIAMOND BITS AND
REAMER SHELLS
Sales and Resetting Service
throughout the World by
Joy Manufacturing Company



*Consult
a Joy
Engineer*

JOY

WORLD'S LARGEST BUILDER OF CORE
DRILLS, ROTARY BLAST HOLE DRILLS
AND MOTORIZED DRILL RIGS



Headframe is atop one of the two shafts at Johns-Manville Jeffrey mine. Underground operations produce about 72 pct of Jeffrey's asbestos.

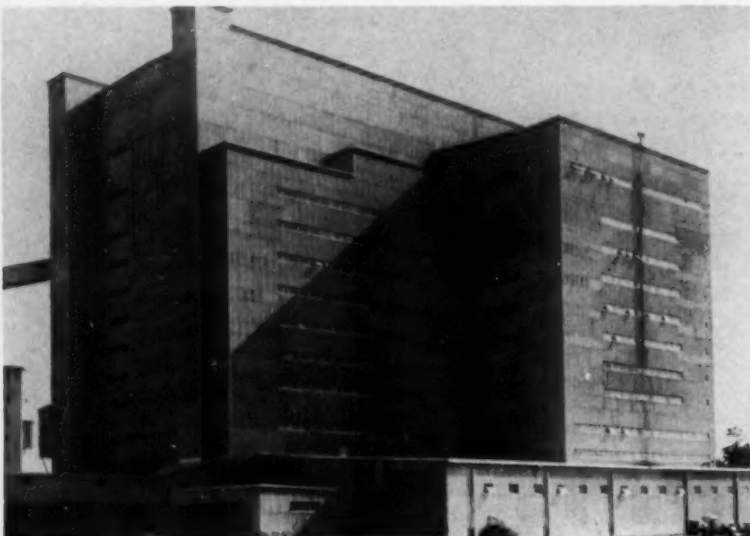
a total annual production of 625,000 tons of asbestos fibre, and a daily capacity of 60 carloads aggregating 2500 tons. Adjacent to the famous JM Jeffrey mine, the new mill will draw on ore reserves for more than 100 years of operation at the present rate of production.

Equipped with the most modern lighting, safety devices, and dust control equipment, the new Johns-Manville asbestos mill is expected to provide the safest and healthiest working conditions of any fibre mill in Canada or the U. S., company officials say.

There are 4000 separate dust enclosures, utilizing 4 miles of piping and 12 miles of control wiring in the dust control system. It takes 30 acres of cloth to provide bags used in filtering dust as the ore is milled. When in full operation, the new mill will have air handling equipment capable of purifying air at 2.5 million cfm.

There are 5000 separate safety guards on the milling equipment and more than 4600 fluorescent lighting units.

In 1953 production of asbestos fibre in Canada amounted to 911,713 tons at a value of \$87,633,124. This was 65 pct of the Free World's asbestos production. Of this output, 97 pct was exported, mainly to the U. S. The U. S., which consumes some 70 pct of the Free World's production, gets 70 pct of its supply from Canada. Johns-Manville, alone, produces more than half of the asbestos fibre mined in Canada, providing jobs for more than 2600 men and women at the Asbestos, Que., mine, mill, and plant operation with an annual payroll in excess of \$10 million. The company operates a second asbestos mine and mill near Matheson, Ont. This is known as the Munro mine, which produces about 25,000 tons of asbestos fibre annually.



World's largest asbestos mill will have a production capacity of 625,000 tons annually when completed in 1956. Shown is the first half of the building now in operation. The mill is of steel and concrete construction and covered with Johns-Manville Transite corrugated asbestos-cement sheathing. When finished building will have 22½ acres of floor space.

Each of the eight fans in the air handling setup at the Jeffrey mine has a capacity of 123,000 cfm and are used in the aspiration of asbestos fibre from the ore milled in the building and for the mill's dust control system. At the left are bag filters. When completed, air handling equipment will have a capacity of 2.5 million cfm.





Cyanamid REAGENT NEWS

DRY AEROFLOAT® PROMOTERS *selective and synergistic*

This group of nine Dry AEROFLOAT Reagents was developed to provide the powerful, selective promoting properties of Liquid AEROFLOAT Promoters in dry reagents having little or no frothing characteristics. They have a wider range of promoting and collecting properties than comparable liquid promoters and are compatible with all types of frothers.

Being water soluble, Dry AEROFLOAT Promoters are easy-to-feed even in small quantities; 5% to 10% water solutions are commonly used. Frequently, they are used as "boosters" for Liquid AEROFLOAT Promoters to increase promoting power without affecting froth characteristics.

Combinations of Dry AEROFLOAT Promoters with xanthates, the 400 Series Cyanamid Reagents or Liquid AEROFLOAT Promoters produce a synergistic effect whereby the dual promoter gives better results than equivalent amounts of either promoter alone.

Very substantial tonnages of Copper, Zinc, Gold and Silver ores are being floated with AEROFLOAT 203, 208, 211, 213, 226, 238, 243, 249 and Sodium AEROFLOAT Promoters.

Cyanamid Field Engineers can help you to short-cut your own testing by giving you the benefit of their knowledge of previous experience with AEROFLOAT Promoters, alone and in combination with various other promoters.

AMERICAN *Cyanamid* COMPANY



MINERAL DRESSING DEPARTMENT

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

Cable Address — Limonitra, New York

NORTH AMERICAN CYANAMID LIMITED
Royal Bank Bldg., Toronto 1, Ontario, Canada
CYANAMID DE MEXICO, S. A.,
Apartado No. 26012, Mexico 12, D. F., Mexico

CYANAMID PRODUCTS, LTD., Bush House,
Aldwych, London W. C. 2, England
SOUTH AFRICAN CYANAMID (PTY.) LTD.,
P. O. Box 7552, Johannesburg, Union of South Africa

E. P. CADWELL, Casilla 12983,
Correo 11, Santiago, Chile
G. B. O'MALLEY, MALCOLM GLEN,
377 Little Collins St., Melbourne C. 1, Australia

Uneven, Intermittent Flow

DO YOU SUFFER FROM ANY OF THESE CONVEYING "HEADACHES?"

Abrasive or Sharp Edge Material

Steep Inclines

High Tonnages

Heavy Loads

Material Too Hot
to Handle

**you
need
a**



A Rex Pan Conveyor carrying hot ore nodules from kiln to railroad car up a 25-degree incline.

REX Apron or Pan Conveyor

Hot or cold, free-flowing or lump, abrasive or non-abrasive, you name the material, and we'll show you how to handle it better...cheaper...easier with a Rex Apron or Pan Conveyor.

Your Rex Conveying Engineer has years of experience in solving difficult materials handling problems, and he's backed by a complete line of Rex Apron and Pan Conveyors as well as the finest in belt idlers. He can recommend without prejudice the exact type of conveyor which best suits your particular application. He'll explain in detail the advantages of Rex design and construction. For instance:

★ Unique outboard roller construction permits easy servicing without disassembling chain or conveyor.

★ Exclusive Rex Square Through Rods seated in square holes in side plates positively cannot rotate.

★ Only a minimum of mechanical servicing is required.

★ Steep inclines are practical.

★ Power requirements are low because of large diameter outboard rollers.

Want more information? It's as near as your telephone. Call your nearest Rex Field Sales Engineer or write to Chain Belt Company, 4794 W. Greenfield Ave., Milwaukee 1, Wis.



Chain Belt COMPANY OF MILWAUKEE

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland • Dallas • Denver
• Detroit • El Paso • Houston • Indianapolis • Jacksonville • Kansas City • Los Angeles • Louisville •
Midland, Texas • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh • Portland, Ore.
• West Springfield, Mass. • St. Louis • Salt Lake City • San Francisco • Seattle • Tulsa • Worcester

Distributors in principal cities in the United States and abroad

Export Offices: 4800 W. Mitchell Street, Milwaukee, Wisconsin; and 19 Rector St., New York City.



UNDERGROUND PRODUCER

Underground in mines, construction jobs — the Eimco 105 with the Eimco excavating attachment is the big producer.

Loading trucks with abrasive heavy ore at the rate of 8 to 10 tons per minute, Eimcos in this mine, have steadily reduced the cost of loading ore every month since their installation.

Eimcos are built to withstand the most severe treatment working on uneven bottoms, digging in blocky, broken rock and moving in narrow passages or big rooms with definite limitations in headroom.

Unusual Eimco features make them a stand-out for performance. Some of these features include frame mounting of the excavating attachment to provide for free oscillation of the tracks at all times, variations in Rocker-Arms and buckets to meet all requirements for headroom and material to be loaded. Independent track control with finger tip operating levers and many other exclusive features.

Write for complete information.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Duluth, Minn. Kellogg, Ida. London, Eng. Paris, France Milan, Italy



You Can't Beat An Eimco!



Three penthouses were installed in this service shaft so that working force required to combat weak ground conditions could be accommodated. Overbreak necessitating huge quantities of concrete is shown in this shot of the No. 22 level.



Eimco 40 H loader is used to handle ore from the sill on the No. 19 level. The Eimco has proven to have a greater loading capacity than other equipment used at New Broken Hill. Production this year is expected to approach 400,000 tons.



Old type scraper hoes were proving troublesome. The heavier type with replaceable blades resulted from research efforts. Loosening of the digging blade was one fault of the old equipment that has been solved by this new design.

New Methods Boost Australia's Broken Hill Output

Down under, where one of the big worries around Christmas time is the danger of sunburn, New Broken Hill Consolidated has moved from fourth to second place on the list of producers in the famous Australian lead-zinc field. Ore production last year approached 400,000 tons, compared with 239,922 tons for 1952.

Recent ore development has been largely on the No. 19 level. A flattening in pitch of the No. 1 Lens orebodies was disclosed. This pitch flattening was also found in No. 2 and 3 Lens orebodies and indicates that the main mass of ore lies higher than previously thought. Thus, No. 19

and 20 levels may mean much greater production than anticipated.

Sinking the service shaft last year was delayed by weak ground conditions, which necessitated use of additional labor. This meant that extra points of attack were required. These were provided in the form of three penthouses installed in the shaft. The first penthouse was placed a short distance from the surface. It permitted work to continue below while the sinking headframe was dismantled and another headframe constructed. Other penthouses allowed installation of shaft sets below No. 8 level while stripping and concret-

ing was carried out at the shaft bottom. When the permanent headframe rose to 67 ft, it was possible for another group to begin installing shaft sets from the surface.

Metallurgical Research

Broken Hill's metallurgical research dept. has been in operation for more than a year. Some of the projects undertaken by the Broken Hill metallurgists have centered around the variation in ore type as underground development advances. The presence of bismuth has shown signs of increasing toward the south. However, investigation indicates that



No. 1 airway is being converted to a downcast for main air intake to the Zinc Corp. mine. Close timbered octagonal extension was added to deepen the airway. Broken rock was shrunk away as the airway advanced upward from No. 18 level. The method has not been used before at Broken Hill or probably in Australia.



A NBHC miner operates a three-drum scraper winch, illustrating the freedom of operation experienced with a dead-man anchor. Additional tonnage is being handled in the same time formerly required because of new and improved equipment.



Two metallurgists, at the research dept. installed by NBHC, operate a Humphrey spiral and Wilfley table to produce a concentrate from portion of the combined Zinc Co. and NBHC residue. Flotation research is one of the main projects.



This 4-in. drifter is for blast holes up to 50 ft in length. A color code indicating the bit gage of drill steels has been introduced. Drifter is mounted on a bar and arm rig and uses jointed drill rods with detachable tungsten carbide-tipped bits.

bismuth content of lead concentrates obtained from zinc lode ore was considerably higher than that obtained from ore in the lead lode. Instead of answering problems the project has stimulated other questions.

Another problem that has attracted the attention of Broken Hill metallurgists is the effect of the lubricant used in rock drills on the recovery of lead and zinc minerals by flotation in the mills. Laboratory tests revealed that one rock drill lubricant has a detrimental effect on flotation. An attempt has been made to find out if any one constituent of the oil caused the trouble.

The introduction of shrinkage stopping may have some effect on the ore treatment because, after breaking, the ore may be held in stopes for several years. Sulphide lead and zinc

minerals are liable to oxidize, causing difficulties in selective flotation.

New ore at a new mill always presents problems. The Broken Hill mill was first operated in September 1952. Before that time ore had been treated in a sister operation mill, the Zinc Corp. Thus, while the mill was operated smoothly, it must be realized that the ore mixture treated in the new mill is somewhat different from that in the Zinc Corp. unit. The amount of copper relative to the amount of lead is higher at Broken Hill and there is more pyrrhotite.

Ore Mining Improvements

Fill stoping and flat back cut methods have improved mining. Electric blasting has given better fragmentation with fewer holes, using milli-second delay detonators in stopes 15

ft wide or more. Holes were drilled during tests with lightweight jackhammers mounted on airlegs. Tungsten carbide tipped alloy drill steels were employed.

Development of the trial sublevel stope on No. 16 level has made it necessary to drill holes up to 50 ft in length as this stope started production. Results indicate that a 4-in. diam piston drifter mounted on a bar-and-arm rig and using jointed drill rods with detachable tungsten carbide tipped bits may prove the most suitable.

Another innovation at Broken Hill is the employment of hydraulic boom drill carriages, originally designed for mounting large drifters, for lifting caps into position during gangway timbering. The carriages were fitted with supporting cradles.



A modified hydraulic boom drill carriage is used to lift a cap into position during gangway timbering operations. The carriages were modified by fitting supporting cradles. Originally, the carriages were designed to mount large drifters. Broken Hill has developed several other innovations using standard equipment.



The loader operator is also the motorman in this operation. Results — high production per man shift.

LOW COST PRODUCTION

Tonnage loaded into cars for transporting to the surface is the tonnage measured for mine production.

Dependable loading equipment and efficient loading methods are more responsible than any other factor in keeping production up.

Eimco loaders in conjunction with drawpoint mining systems, have in many cases been found to be the most productive method on a ton-per-man shift basis. These facts are explained in recent papers by operators who have used chute and grizzly systems and scam drift scraper systems as well as combinations of both.

Write for your copy of these papers and information on drawpoint production loading with Eimcos. These will be your guides to greater tonnages at lower costs.

THE EIMCO CORPORATION


Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Detroit, Mich. Kalamazoo, Mich. London, Eng. Paris, France Milan, Italy



Stops Blinding

Increases Capacity — Cuts Screening Costs



THERMO-DECK Heating Unit


You can screen fine, moist material *continuously* with a *Thermo-Deck* heating unit. No down time required to clear fine or medium mesh screen cloth!

Heated screen cloth remains open . . . you get *more* tonnage through the screen and better separation.


Operating records prove that heated wire cloth screens last up to three times longer than non-heated cloth, because they do not have to be pounded free of blinded material. For the same reason, you save man-hours too. These lower costs increase your profits.

The *Thermo-Deck* unit can be applied to Allis-Chalmers screens in the field. See your nearby Allis-Chalmers representative for complete details. Or write Allis-Chalmers, Milwaukee 1, Wis., for Bulletin 07B7812.

A-4372



POWER ON, *Thermo-Deck* heating unit keeps screen cloth clear on vibrating screen handling fine, moist material.



POWER OFF, troublesome blinding occurs. This view shows same screen as above, with *Thermo-Deck* unit shut off.

For Intermittent Feed...ADD A STA-KLEEN DECK

If feed is intermittent, fine material may bake on the wire cloth during interruptions in feed. Heat which ordinarily is absorbed by moist material increases the temperature of the wire cloth sufficiently to cause any fine material to bake on. The addition of a *Sta-Kleen* deck effectively prevents this. Bouncing rubber balls between the screen cloth and a ball retaining deck clear the cloth of baked-on particles.



ALLIS-CHALMERS

Thermo-Deck and *Sta-Kleen* are Allis-Chalmers trademarks.



THAT willfull child of the 20th century, atomic power, is beginning to show signs of growing up. Whether it will ever reach an age where it's more rambunctious tendencies are curbed depends largely on environmental factors—which the Soviets play no little part in creating. Three news events, almost tumbling over each other in their sudden appearance upon the American scene, bode well for the future. The first was the passing and eventual signing of the new atomic energy legislation fought for by the President.

When President Eisenhower signed the new law he opened the way for a future private atomic industry. Passed after much debate, vituperation, and adherence to party lines, the law also provides for international cooperation between the U. S. and allied nations. Under certain security regulations the U. S. can now share atomic knowledge with friendly countries.

While the bill has become law there are several provisions that the 84th Congress is expected to re-investigate. One matter is the compromise reached after 13 days of filibuster which requires that companies share for five years any atomic power patents.

The law allows the Atomic Energy Commission to grant 40-year renewable licenses for private industries to operate atomic facilities and to handle fissionable materials. The Government retains title to all fissionable materials discoveries. Publicly owned utilities and cooperatives are to receive first preference for use of publicly owned power developed by AEC experimental plants.

The U. S. can now share secret details on the external characteristics of atomic weapons and also is in a position to supply allied nations with methods of performance and defenses against atomic war.

The second and third events came simultaneously. President Eisenhower waved a neutron wand to start excavation for the first commercial electric plant in the nation to be powered by atomic energy. The President in Denver activated an unmanned 14-ton shovel some 1200 miles away in Shippingport, Pa., which scooped up 3 tons of earth, moved forward, and then dumped the load. The plant is a joint project of the AEC, Duquesne Light Co., and Westinghouse Electric Corp. Rear Admiral E. G. Rickover, the commission's director of the project, said that Government's share would be about \$33 million, with Duquesne paying about \$13 million toward the plant cost. While the cost of producing electricity using atomic power is expected to be greater than by conventional coal burning plants, designers hope to eventually produce an economically competitive atomic power plant.

Westinghouse is building the reactor under contract with the AEC. Duquesne will build the generating part of the plant at its own expense. It will operate the plant and pay the commission for steam generated by the reactor—whose ownership is to be retained by the Government.

Third on the list of events was the announcement from the President that a world agency for the dissemination of atomic energy knowledge is being

formed. Prospective members of the pool are Great Britain, Canada, Australia, South Africa, and France. There will be others. Talks are in progress with several nations. Negotiations are also underway for the construction of an atomic power reactor in Belgium. Raw uranium and fissionable materials will be set aside for agency use, the President announced. Disclosure of the move toward formation of the pool came during ceremonies connected with the Shippingport project.

President Eisenhower first broached the world atomic pool idea before the United Nations last year. What part the UN will play in the agency is yet undetermined. Thus far, the attitude of Russia toward the pool has been almost completely negative. One source pointed out, however, that political embarrassment finally forced the USSR into the Technical Assistance program after many years of non-contribution. In his UN speech, President Eisenhower said that the agency would aim at the application of atomic energy to medicine, agriculture, and other peaceful activities. Speaking to the audience watching the Shippingport ceremony, President Eisenhower said: "We have just agreed with a number of other nations to go ahead now with the formation of an international agency which will foster the growth and spread of new atomic technology for peaceful use. Atomic materials for projects sponsored by this agency will be set aside for that purpose. We hope that no nation will long stand aloof from the work of this agency."

Participation in the agency by the U. S. is subject to Congressional approval under amendments adopted in the new atomic energy law. Press Secretary James C. Hagerty noted that the project had nothing to do with weapons. There was no immediate reaction from Moscow. Tass was slow in reporting the move in the Soviet press and major government figures were reported to be out of town that particular week-end.



INDIA'S need to develop industry is slowly emerging from the planning stage and actions are replacing words. One of the major problems, of course, is the overpowering amount of metal imports. Replacing those imports with domestic production is one of the prime targets of the Indian Government.

It has been learned from V. C. Saptarshi of Ramdaspeth, Nagpur, India, that his nation's imports of nonferrous metals amounts to 140 million rupees annually. Thus, an announcement from the Union Ministry of Natural Resources & Scientific Research that India is to be subject of an intensified search for nonferrous metals, comes as no surprise. Another possible area where India may be able to replace imports with domestic material is sulphur. The Maharajah Karni Singh of Bikaner feels that the installation of a sulphur plant near Bikaner is eco-

nomically feasible. Raw materials could come from neighboring areas. Technicians have come up with statistics that show that sulphur could be produced for about 25 pct of the import cost.

India faces several problems in developing a steel industry. Not the least of these is the desire of many sections of the country for a plant. Each state tosses its oar in and if the offer is refused, political repercussions can be expected. Following recommendations by German experts it was decided to locate one steel mill in Rourkela. A second plant may be located at Madhya Pradesh, with a third plant also under consideration. With four states arguing that individually they offered the best mineral and other resources, it may be said that a certain amount of unhappiness exists in those areas not considered suitable.

Equipment is being acquired for the uranium and thorium plant at Bombay. The plant should be completed by the end of 1954. Annual production is estimated at about 200 lb of thorium nitrate.



WITH almost no fanfare at all lignite has been growing in importance as a source of electric power. Right now, lignite represents about 25 pct of the nation's coal reserve in tonnage and about 15 pct in terms of heating value. At the fall meeting of the American Society of Mechanical Engineers it was pointed out that power requirements within the area of economic use of lignite are growing in a proportionate rate to the nation as a whole.

About 95 pct of U. S. lignite reserves are in the Dakotas and Montana, where supply adds up to more than 450 billion tons. Power plant use of this fuel is largely confined to areas within the economical rail distance from the mines.

H. R. Cowles, Otter Tail Power Co., Fergus Falls, Minn., reporting on trends in lignite fired power plant units, said the size of turbines and boilers burning lignite is growing rapidly. Within four or five years there may be boilers of 500,000 to 600,000 lb per hr capacity, more than double the capacity of the present largest unit of 250,000 lb per hr, still under construction. He believes that before 1967 there will be 100,000-kw turbine generator units supplied with steam from lignite-fired boilers.

Little concern was expressed over the effects of hydroelectric developments along the Mississippi River in supplying all power needs. Mr. Cowles stated that 1960 estimates for Garrison Dam show gross peak capability of 385,000 kw in July and a minimum of 180,000 kw in November and December. A dry year would make the estimate even less. The present integration of the Missouri River hydroelectric generation and other major systems will require fuel burning plants to supply power deficiencies in adverse water and to meet peak demands for power, which in North Dakota occur when there are restrictions on the capacity of the river channel.

THOMAS ALVA EDISON and the diamond jubilee of the electric light bulb will be observed this month at the Henry Ford Museum and Greenfield Village, Mich. The 25th anniversary of the museum and village will also be commemorated. Recently, MINING ENGINEERING carried an article outlining some of Edison's mining activities that predate current taconite developments. One more item in the rather spectacular career of Mr. Edison was later brought to light during a conversation with Stewart S. Fritts, general superintendent of the Lone Star Cement Corp., Richmond, Va. Chatting with Mr. Fritts it was discovered that Edison turned to Portland cement manufacture when uneconomic prospects of the iron-ore field became evident. Mr. Fritts' knowledge comes to him first hand.

"My grandfather sold his farm to Mr. Edison in 1900 as part of the quarries and property holdings involved in the cement venture. Most of the processing machinery used at the Ogden iron mine was moved to Stewartsville, New Jersey. Even that big shovel they used at Ogden became part of the cement operation. They dug 'cement rock' as the cement making materials are known in the Lehigh Valley of Pennsylvania and the Pohatcong Valley of New Jersey."

Mr. Fritts noted that the giant rolls referred to in the article were "still in active use at the Edison Cement Corp. plant near New Village, New Jersey, until the plant was dismantled and the machinery shipped to Chile for use in a new cement plant in that country."

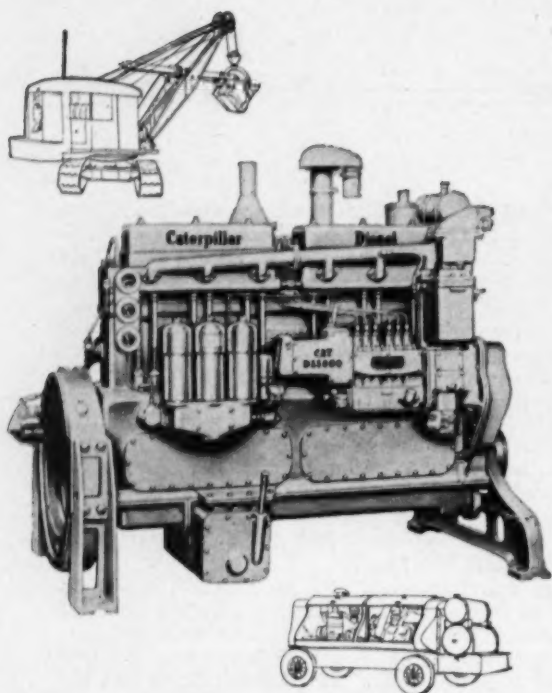
An inquisitive look may have brought forth this particular observation from Mr. Fritts. "It would appear that iron-ore processing and cement manufacture have little in common. But let's look at the thing from a metallurgical point of view. Both require quarrying, crushing, grinding, blending, and pyro-processing."

Mr. Fritts detailed some of the patents held by Mr. Edison. While not generally known, Mr. Edison had controlling patents for the air separation of minerals and the use of the long kiln. "Operating records show kiln efficiencies with fuel rates of less than 800,000 Btu per barrel. It corresponds to some of the best of modern operations. To be sure, the unit capacity was low by modern standards, but even at that, the plant had a total daily capacity of nearly 30,000 bags of cement and employed more than 400 men."

Belt conveyor designs initiated at the Ogden plant were further developed at the New Village plant. According to Mr. Fritts, one conveyor had nearly a quarter of a mile of belting.

"Mr. Edison seemed to have a deep-rooted distrust for elevators and it was quite common to see several lengths of belting scaling an incline. At one time it's supposed to be true that cement materials in process traveled more than 13 miles on belt conveyors in the journey through the plant."

M. A. Matzkin



CATERPILLAR ADVANCED DESIGN FEATURES IN THE NEW D13000

While retaining such time-proved features as aluminum alloy main and connecting rod bearings, "Hi-Electro" hardened and Superfinished bearing surfaces, exclusive Caterpillar fuel injection system, ability to use low-cost No. 2 furnace oil without fouling, etc., the new D13000 incorporates many new features, among them:

NEW Valves, Inserts, Rotators—new components, standard in the breathing system, combine increased breathing ability with longer valve life—make possible additional horsepower output and lower maintenance costs.

NEW Vibration Damper—sturdy, metal-enclosed, fastened directly to front of crankshaft. Keeps unit vibration-free at higher speeds. Optional in installations where engine speed is kept below 1000 r.p.m.

NEW Camshaft—improved high lift cam profiles give smooth valve seating and increased breathing ability. This increased capacity, also made possible by new oil-bath air cleaner and larger intake and exhaust manifolds, insures low exhaust temperatures and adequate reserve power.

NEW Water Pump—larger, with a greatly increased capacity to answer cooling needs of this modern, high-powered diesel.

NEW Pistons—oil-cooled, made of high-strength, lightweight aluminum alloy with stainless-steel heat plugs in the high-temperature zone and cast-in iron bands for the top ring groove to give best service at lowest final cost.

NEW Oil Pump—features not just one, but two pressure controls to assure correct lubrication for all moving parts from the first turn of the crankshaft.

For complete details, specifications, attachments, etc., see your nearby Caterpillar Dealer

Announcing the

NEW 190-HP CAT* D13000 ENGINE

**...yours for greater
power, production, profits!**

For years, working in all kinds of construction equipment, conditions and jobs, the Caterpillar D13000 Engine has proved itself a big money-maker for power users. Now, here's a new D13000, designed and built to bring you even greater power, production and profits!

In the new D13000, you get 21% more brake horsepower. Its governed speed, raised to 1200 r.p.m., provides greater versatility and productive capacity. While keeping outstanding, time-tested parts, it adds advanced design features to set new standards of stamina, dependability, economy and long life. And its wide variety of matched accessories and attachments makes it readily adaptable for any need.

For jobs requiring power in the 145 (continuous) to 190 (intermittent) horsepower range, your best buy is this rugged new Cat D13000 Engine. Leading manufacturers of excavators, crushers, compressors and other heavy-duty machinery can furnish it in their equipment. Get the complete facts about it today from your nearby Caterpillar Dealer.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Both Cat and Caterpillar are registered trademarks—©

**D13000—
A NEW STANDARD
OF DIESEL POWER**

Drift of Things

Dear Mr. Cooley:

The apparent unattractiveness of the mining industry to young men entering college has made a big splash in a number of the mining publications. Many words have been written and spoken in attempts to rectify the situation, but none of them have the ring of conviction. Too much attention has been paid to promoting the importance of the industry as a whole and almost none to the importance of the jobs within it. Certainly a young man is concerned with the place occupied by mining in the overall economic picture, and with the salaries paid to its employees, but he also has a definite and strong desire to feel important as an individual, and this is where mining seems to fall down.

The want ads for technical help in the publications of industry all sound very much alike. The requirements are basically similar for all industries and the salaries are reasonably consistent. The manpower demand does not seem to be noticeably greater in other industries. Yet with all these similarities, mining still falls behind in college enrollments so there must be other reasons.

Certainly no one seriously doubts that there will be a continuing demand for the products of mining. And it is obvious that the rapidly progressing depletion of high grade ore reserves is forcing mining more and more into a dependence on technical research by qualified men. Therefore it cannot be reasonably assumed that the future of mining and metallurgical technicians is insecure because of any impending dissolution of the industry. There remains only one real area of doubt in the minds of prospective mining engineers: the doubt that they will be accepted as individually important contributors to the future success of the industry.

To return to the want ads for a moment, they all tend to produce an impression of the importance of the job to be filled. If the job were not important, why would the standards for employment be set so high? This condition is almost universally prevalent, no matter what the industry. When the applicant comes into contact with the personnel department on a more personal basis through the application blank he is frequently required to divulge the innermost secrets of his personal life and that of his family. Finally, in the personal interview, he must be alert, personable, and congenial and must answer more searching questions to the satisfaction of the employer. By this time he is convinced that the vacancy for which he is applying must be extremely important, and he may have some qualms about his ability to fill it adequately. Even though they have not been discussed, the applicant probably has formed a subconscious picture of modern facilities, good organization, and adequate living conditions all prepared and waiting for the important man who finally lands this job which has such demanding requirements.

In many industries this picture is fulfilled at least to a reasonable extent. The successful applicant is led into a clean, well-lighted, well-ventilated drafting room or office where the furnishings and equipment are modern and are arranged conveniently for the work to be done. He is introduced to the people with whom he will work, and all concerned are shown his place in the production team. He finds that allied functions such as blueprinting, filing, messenger service, and the like are taken care of by special personnel in such a way that he is able to concentrate on the work for which he was selected. If he was brought into the locality from another area, there is frequently a housing service run by the company which assists him to find adequate quarters for himself and his family. And he is often assigned to a special parking lot and given a sticker for his car to show that he is truly entitled to the privilege of parking there.

The result of this treatment is the feeling that the work to which he is assigned must be important or such pains would not have been taken to equip and organize for it. With the feeling that his work is important, he himself feels important and consequently interested in the job and the industry.

Contrast this reception to the one often accorded the mining applicant who has been through the same trials to get the job and approaches it with the same picture of the job's importance. He is led into a dingy, dusty room with dirty windows, poor illumination, inadequate heating and ventilation, and a view of the scrap pile outside the machine shop. His assigned drawing board is probably a makeshift on wooden horses equipped with a rickety stool and a worn-out T square. Often this equipment is set up after he reports to work and must first be dug out of storage and cleaned up before it can be used. Then he finds that he will be required to do his own blueprinting, run his own errands, and figure out the antiquated and outgrown filing system in order to do the work for which he was hired. Frequently he must accept such company housing as is available, and the chances are that it isn't much compared to what he has been used to even in college.

By this time he has started to wonder not just if the job assigned to him is important but if there is even a job for him to do. With a psychological hurdle like that it is doubtful if he would be able to do his best work, and with all the extraneous duties to distract his concentration, his enthusiasm is further dampened. Most certainly he does not feel very important.

This description of mine office and organization is not universally applicable, nor is it necessarily typical. But personal experience has proved it to be common enough to give mining engineering a reputation sufficiently unsavory to be discouraging to young men looking for a career.

There is no way of eliminating the essentially pioneering quality normal to mining because it has always been necessary to mine where the ore is, and this is seldom in a civilized locale. But this pioneering aspect of mining is one of its real attractions and is probably an asset rather than a liability. Nevertheless the standard of living to which most of our young men have been accustomed must be taken into account if they are to be attracted to mining and held in it. This is particularly true when considering their wives and families.

Father is no longer the family autocrat he was when mining was young in this country, or even 50 years ago. Wives and families have a great deal of say in the selection of living accommodations and social and recreational facilities. Consequently living accommodations and community activities must be brought up to snuff and kept there.

I hold no brief for coddling and pampering personnel beyond reasonable limits. The only point under discussion here is the value of making evident the importance of the work to be done by the individual so that he can have the necessary self-satisfaction of feeling he is important if only because he was chosen to perform what is obviously an important function. In order to accomplish this it must be obvious to him from the physical and organizational arrangements made for the job that the specified qualities, experience, and training are actually required by the work and that they are to be utilized as fully as possible under the best obtainable conditions. This concept can be expanded to cover housing and community facilities, because these must also be adequate to meet the personal and intellectual needs of the type of employee desired and of the type of family such a man would be expected to have. In this connection consideration must be given to the increased leisure time provided by modern work hours, home furnishings, and equipment.

To sum up, mining needs to use concrete evidence to show young men and their families that they are needed, wanted, and planned for. This is the only way in which they can be attracted to the mining industry.

Lucien Eaton, Jr.

Amen!

Charles M. Cooley

Reserve's E. W. Davis Works Installs New Heat Hardening Process for Taconites

Allis-Chalmers Mfg. Co. and Arthur G. McKee & Co. cooperated in this new approach to heat hardening of taconite pellets promising easy quality control, minimum breakage, and operating simplicity.

SUCCESSFUL development of a new process for heat hardening of pellets made from taconite concentrates was announced by Arthur G. McKee & Co., steel plant engineering and construction firm of Cleveland, and Allis-Chalmers Mfg. Co.

An order for the design, engineering, and materials for a plant incorporating the process, has been received by the McKee Co. from the Reserve Mining Co. for its new E. W. Davis Works at Silver Bay, Minn. It is estimated that this plant will cost around \$19 million and when in full operation, will turn out 12,000 tons of pellets per day.

In a joint announcement of the new development, Merrill Cox, vice president of the Metals Div. of McKee, and G. V. Woody, manager of the processing machinery dept. of Allis-Chalmers, outlined major advantages of the new metallurgical process:

Extreme simplicity of operation; utilization of heat recovered from the operation; ease of quality control resulting from ability of the operator to see what is going on during the process; direct and simple dis-

charge of the product from the equipment; and minimizing of breakage of the pellets because of stationary position on the grate carrying them through the furnace.

The two companies agreed that these advantages mean more efficient operations for processors of taconite concentrate, thus effecting cost savings not found in other agglomerating processes.

The development carries tremendous significance to the entire iron ore and steel industry.

Minnesota taconite contains approximately 35 pct iron oxides, 5 pct iron carbonates, 20 pct iron silicates, and 40 pct gangue. After concentration and agglomeration, a product containing between 60 and 65 pct iron is obtained, as against the 50 to 52 pct usually found in the direct shipping ore from the Mesabi range.

Several hundreds of tons of concentrate were processed into pellets in the small pilot plant at Carrollville, Wis., owned by Allis-Chalmers. Since Reserve Mining's much larger plant at Babbitt, Minn., was started last February, thousands of tons have been processed by the new method. This plant is capable of producing 1000 tons of pellets per day. The McKee Co. designed the pelletizing section of this plant and assisted in supervising its construction.

The new process is based on the utilization of a horizontal furnace, approximately 200 ft long, through which moves a 6-ft wide traveling grate loaded with pellets, plus auxiliary equipment for ball making or pelletizing. Ball making consists of continuously feeding concentrate into large rotating drums which rotate at a predetermined speed. The balls formed in the drums are approximately $\frac{3}{8}$ to $\frac{1}{2}$ -in. diam, contain about 10 pct moisture and the required powdered anthracite coal for burning.

These balls are fed onto the grate by a mechanical oscillating feeder at the rate of about 50 to 55 tph. The first stage is drying and preheating of the pellets; and then hardening in a combustion stage.

Pellets are ignited at a temperature range of 2300 to 2400°F. Complete burning is accomplished by the propagation of the heat down through the 15-in.-deep bed at a rate of approximately 1 in. per min. The molecular change in the concentrate generates its own heat, amounting to about 40 pct of process requirements. Large volumes of air are required.



First step in the pelletizing and heat-hardening process is discharge of balls from balling drum to a vibrating screen where undersize is removed. Balls go to the furnace on traveling grates, while undersize is returned to the drum to act as seed pellets.



Early experiments on the horizontal traveling grate began in the laboratories of Allis-Chalmers Research Div. O. G. Lelopp, who developed much of the heat transfer principles used in the horizontal traveling grate, is shown between two development engineers who worked on the project.

Burning of the pellets takes place within approximately a 30-ft section of the machine, the grate portion moving forward at the rate of about 30 in. per min. The machine is so designed that the retained heat in the burned pellets is recovered and utilized for drying and igniting the green pellets at the feed end of the machine.

In order to facilitate handling, the burned pellets are cooled on the grate by pulling large volumes of cold air down through the bed. Pellets are discharged from the machine and screened to remove small particles before loading for shipment by rail and lake.

The entire development started out in a small experimental pelletizing furnace in the laboratories of the Allis-Chalmers Research Div. From these experiments grew the pilot plant at Carrollville and from this pilot plant grew the commercial operation.

Pelletizing Operation at Pilot Plant

Taconite concentrate goes first to a repulping tank where a metered amount of make-up water is added, and repulping is done by two impeller agitators. Slurry is pumped to a drum filter. The drum filter removes any excess, leaving approximately 10 pct moisture in the feed to the pelletizing operation.

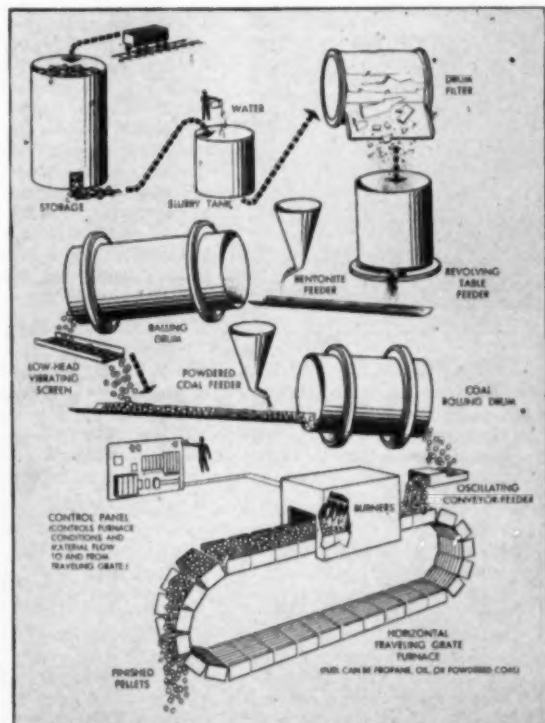
Filter cake drops onto a belt conveyor that takes it up to a table feeder. Concentrates from the table feeder pass onto a belt conveyor that goes to the pelletizing drum. A small vibrating feeder meters additive which acts as a bonding agent to reduce the possibility of breakage when the concentrates are rolled into pellets, or balls.

The concentrates next go into the revolving pelletizing or balling drum. Concentrates enter at the higher end and pellets are discharged at the lower end. Acceptable pellets are about $\frac{1}{2}$ in. diam.

A vibrating screen under the discharge end of the balling drum removes undersize pellets which are returned to the belt feeding the balling drum. Upon entering the drum for the second time these pellets act as seed pellets and keep the balling process going.

Correct size pellets pass across the vibrating screen, fall onto a conveyor, pass under a coal feeding device, and enter the coal reroll drum. In the coal reroll drum the pellets go through the same type of action as in the balling drum, but here the powdered coal is rolled into the surface of the pellets.

Pellets then go to the heat-hardening furnace. An oscillating belt conveyor deposits an even layer of pellets across the full width of and to the full depth of the grate pallets.



Pictorial flowsheet indicates process development at the Allis-Chalmers Mfg. Co.-Arthur G. McKee Co. pilot plant at Carrollville, Wis. Several more commercial size traveling horizontal traveling grates are scheduled for the E. W. Davis plant.

The Five Major Advances in Nonferrous Ore Dressing

1. *Shaking Tables*
2. *Fine Grinding*
3. *Hydraulic Classification*
4. *Mechanical Thickeners*
5. *Flotation*

by C. H. Benedict

ENTERING the profession of minerals beneficiation (it was plain garden variety "ore dressing" in those days) I was fortunate that at that time the first major innovation in modern ore dressing practice was being introduced. I refer to the Wilfley table.

You youngsters that came into the game only 30 years ago or even more recently, with flotation machines and reagents as your very ready tool in time of trouble, do not realize what the invention of the Wilfley table meant to us. We had but one physical property of ores to reckon with—specific gravity—and when there was but little difference in specific gravity between the mineral and the gangue, we were in trouble. The jig and the revolving table were our only mechanical equipment for recovering values and so that we might make even a reasonably satisfactory extraction, we had to classify and reclassify, and jig and rejig, and worry about the laws and advantages of free settling vs hindered settling and just tire the minerals out.

The Wilfley table and its successors solved for us the problem of treating fine sands and noncolloidal slimes, and having solved that problem, or at least tremendously improved existing methods, it pointed the way to grinding of the coarser sands to release and thus recover the contained mineral values.

Professor Taggart in his review of the ore dressing problem as published in the Institute's 75th Anniversary Volume rather minimizes the advantage of the Wilfley for treating slimes. He is too young to have had experience before and after or

C. H. BENEDICT, for 50 years employed by the Calumet & Hecla Consolidated Copper Co., is also the author of "Red Metal", published by the University of Michigan Press in 1952.



A former lecturer in hydrometallurgy, AIME Director C. Harry Benedict is the inventor of an ammonia leaching process for native copper ores. He developed a process and flowsheet for reclaiming and treating waste sand, an operation that recovered more than 500 million lb of copper at a profit of more than \$40 million.

This discerning and candid look at progress in ore dressing, or beneficiation was delivered by C. H. Benedict as the 1954 recipient of the **Richards Award**. He spoke at the **Minerals Beneficiation Div.** luncheon at the Annual Meeting, and prefatory to his more general remarks he said, in part:

I can say, with all humility and in absolute honesty, that as I stand here I feel I am only a symbol, an expression if you will, of what the Richards Award signifies—a desire on our part when we established the fund to encourage research and to reward successful endeavor. As I look over this audience I can see many who are as worthy of this distinction as the recipient. It might have been you, or you, or you—and next year it will be you or you. But any or all of the members of the MBD who have contributed to the success of the division by research and sharing the results of that work with the profession are sharers in this honor.

he would have been more impressed. He was absolutely correct, however, when he wrote, and I quote, "Slimes in the United States at least were considered a necessary evil—what could be saved at little expense was velvet, but the operating profit was made from the sands." The introduction of the Wilfley table and its allied types of shaking tables was the first of what I consider the five major advances of the century in nonferrous ore dressing.

Before I proceed with that theme, I wish to digress for a moment and tell you how the timing of the advent of the Wilfley table affected and in a manner proved embarrassing to Professor Richards, the man to whom you owe the present infraction on your time.

You are all familiar with Professor Richard's treatise, *Ore Dressing*, and doubtless some of you were students under that illustrious dean of the profession. It is a monumental work of four volumes, as you know, but you may not remember that the first two volumes were published in 1903 and the last two not until 1909. The preliminary volumes contained flowsheets of every important concentrating unit in this country, the majority visited in person by the author. But it took so long to assemble the data and to get the text published, that much of the information was obsolete before the work was in circulation. This was due almost entirely to the fact that the Wilfley table was revolutionizing the treatment of fine sands and slimes, and this was proceeding while Professor Richards was struggling with his text and the publishers. In his preface Professor Richards pays his respect to the value of the Wilfley table stating that it was a very fortunate event for the cause of ore dressing but most unfortunate for his book, which either should have been published in 1896 before the Wilfley table was introduced in the mills, or not published until 1905 when the adaptation of the mills to the newcomer was complete. He realized the situation and met it by the prompt publication of two additional volumes. The work was thus up to date and it has remained a standard textbook for many years.

I learned one excellent lesson from Professor Richards, and it was not in the field of ore dressing—that lesson was the danger of prophecy. It would be very fortunate for mankind if the older generation could pass on to the younger all the lessons they had learned from their own experience, and accordingly foretell the future trend, whether in science, industry or world politics. There are two schools of thought on the subject: that "One learns nothing from history save that one learns nothing from history," the other the French maxim, "Plus ça change, plus c'est la même chose!", or "The more things change, the more they remain the same." Dear old Professor Richards, having examined and reviewed the whole field of his art, ventured the prophecy that while all was not perfection, still the future would be devoted to increasing the efficiency of current equipment and practice, rather than in the introduction of new methods.

Within a few years acid and ammonia leaching for nonferrous ores was put into practice, flotation was in the development stage in Australia, and gravity methods became relatively unimportant.

There was room for increased efficiency in ore dressing, as Richards indicated. Recoveries were hardly up to 70 pct on sulphide ores and 80 pct as

a maximum on native copper where the gravity differential was so much greater. As late as World War I the largest company of all, Utah Copper, was losing one third of its values. Very briefly, what were the major items that have brought modern recovery percentages into the high nineties? As I mentioned, there were five developments that stand out.

The Wilfley table was the starter. Then with a reasonably efficient and large capacity device for recovering fine particles, the mill men turned their attention to finer grinding. The Huntington and Chilean mills were standard equipment but they were poor tools at best, mechanically inefficient and requiring frequent and expensive repairs. It was not until the invention of the Hardinge mill, pebble and ball, and later of the Marcy that the grinding problem became simplified and within the scope of the smallest operator.

It has always been a mystery to me why the development of ball grinding should have been so tardy in being recognized by the ore dresser. It had been standard practice in the cement industry for years. Fifty years ago I wrote to the Krupps in Essen, Germany, outlining the problem of the desirability of crushing from $\frac{1}{4}$ or $\frac{3}{16}$ in. to 28 or 35 mesh, and the reply came back outlining many reasons why it was impractical. Hal Hardinge evidently did not read that letter. Calumet put in 64 mills in 1913. Inspiration did as much for the Marcy mill with its "one easy step" and the bogey of fine grinding took its flight. This was step No. 2.

But there was still the troublesome problem of hydraulic classification with its attendant dilution. That two-headed monster was attacked and overcome in a small experimental plant in the Black Hills of South Dakota by the current dean of our profession, none other than J. V. N. Dorr. The Dorr classifier outmoded all the V-shaped hydraulic classifiers and eliminated dilution of the slimes.

Following this up with the Dorr mechanical thickener, out the window (not the door) went the V-tanks and the Spitzkasten and the Spitzluten and all that type of thickeners. I am willing to give Mr. Dorr full credit for steps 3 and 4.

Leaving aside now the very important but specialized acid and ammonia leaching processes for copper, zinc, and nickel, the revolution to end all revolutionary processes came in with flotation. Practiced first with the use of any collective agent ranging from tobacco juice to cow dung, it is now a scientific process instead of a hit-and-miss empirical one.

It might now be safe to venture Professor Richards' intimation that we have realized the ultimate in inventive genius and we leave only loose ends for our successors. I will not risk even that statement and will make only the prediction with which I am sure you will agree, that you will not extend recoveries beyond 100 pct. But you will strive to reach that goal, and as a corollary to that, with present practice so highly developed, it follows that every slight gain will require a disproportionate amount of professional cooperation and individual effort. Technical sessions such as this will lead the way and the healthy growth of the MBD is the best assurance that if the members of the Mining Div. will find the ore and get it to the mill, no matter how complex the physical structure, the members of MBD will recover the values.



Tungsten Mining Corp. mill with the grinding and sand concentrating section in the center, magnetic separation and storage in the lower left. The new crushing plant is directly behind the right center portion, but is not visible. On the upper right is the old crushing plant now used for stand-by service.

Steadily Growing Southeastern Tungsten Production

by John V. Hamme

Tungsten Mining Corp. reveals growth from 300 to 800 tpd through expansion, not construction—improved recovery results from evolution, not revolution. Unique touch is infra-red drying.

ONE of the major changes in the re-engineering of Tungsten Mining Corp.'s Vance County, N. C., mill near Henderson was the installation of a new crushing plant with a capacity of 45 to 50 tph. During 1953 the milling rate was jumped from 650 tons to 800 tpd simply by expanding existing facilities, eliminating bottlenecks, and making changes in the existing and new circuits.

Previous expansions in 1951 and 1952 raised mill capacity from 300 tons to 650 tpd. In its latest move, Tungsten Mining decided that expansion of existing facilities would be more economical than building

an entirely new mill. The job was engineered so that normal production was uninterrupted. For the engineering and design of the new crushing plant and mill expansion the services of the Southwestern Engineering Co., Los Angeles, were obtained. The Southeastern Construction Co., Charlotte, N. C., carried out construction, alterations to existing facilities, and the installation of equipment.

Basic metallurgy for the expansion was not changed from that developed by the Tungsten Mining Corp. over a period of about eight years. Principal tungsten bearing mineral is hubnerite, $MnWO_4$, which constitutes about 90 to 95 pct of the tungsten values, with the remaining tungsten occurring as scheelite, $CaWO_4$. Ore occurs in quartz lenses in the

JOHN V. HAMME is Mill Superintendent, Tungsten Mining Corp., Henderson, N. C.

contact zone of granite and highly metamorphosed rock and is readily crushed, but highly abrasive.

Crushing Plant

Ore from underground operations is delivered by truck to a 150-ton steel bin with a 12-in. grizzly. The bin discharges through a single opening controlled by a No. 5 Ross chain feeder, onto a 36-in. conveyor belt traveling 100 fpm. This conveyor has a Dings electromagnetic head pulley for iron removal.

The 36-in. belt discharges onto a short sloping grizzly with 1 3/4-in. openings; fines drop to a 30-in. conveyor while oversize falls into a 18x36-in. Birdsboro-Buchanan jaw crusher set at 1 3/4 in. Discharge of the jaw crusher joins the grizzly fines on the 30-in. conveyor and goes to a 20-in. conveyor carrying the ore to a 300-ton circular steel storage bin.

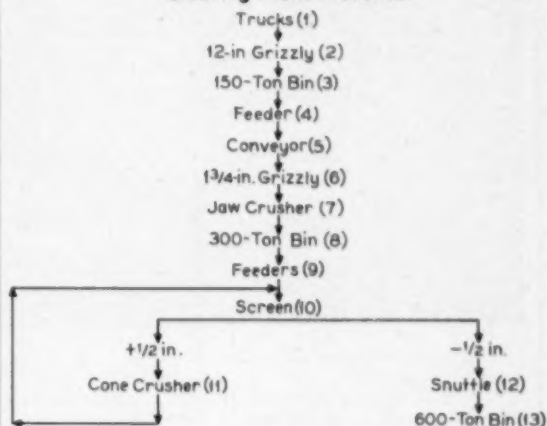
The 300-ton storage bin is discharged through four 16-in. sq openings by two double acting reciprocating pan feeders. Only one feeder is normally in operation at a time. Ore from these feeders falls onto a 24-in. horizontal conveyor which discharges onto a 20-in. inclined conveyor. Transfer of the ore to two more 22-in. inclined conveyors delivers the rock to a 126x60-in. Robins Eliptex screen. A suspended electromagnet ahead of the screen is the final attempt for removal of any tramp iron in the crushing circuits. The screen is equipped with three screen sections having 1/2-in. sq openings. The + 1/2-in. rock falls through a chute to the 3-ft, short head coarse bowl Symons Cone crusher set at 3/8 in. Discharge of the cone crusher is returned to the screen via the two conveyors that also delivered the 300-ton bin product to the screen. The - 1/2 in. product from the screen goes to a shuttle conveyor over the 600-ton suspension bunker fine ore bin by two 18-in. inclined conveyors in series. The shuttle conveyor travels on a track with automatic reversing at each end of the 46-ft bin. Also automatic reversing of the conveyor belt takes place with the reversal of the carriage on the track, thus giving a uniform distribution of ore for the entire length of the bin. All of the conveyors of the crushing plant with the exception of the 24-in. conveyor under the reciprocating feeders of the 300-ton bin and the shuttle conveyor are inclined conveyors with slopes of about 18°. Each conveyor head pulley, except the No. 1 conveyor which has a magnetic head pulley, is provided with rubber scrapers to remove sticky fines from the belts and drop them back into the discharge chutes.

The two 22-in. conveyor belts operate on 20-in. idlers with one troughing training idler and one return training idler on each. These conveyors were originally designed for 20-in. belts, but due to the large load created by the circulating product and the feed conditions, which resulted in excessive spillage, these two belts were increased to 22-in. width without changing the idlers. This arrangement has been highly satisfactory with little spillage occurring.

Mill

Uniform discharge from the 600-ton fine ore bin is accomplished by 11 Stephens-Adamson 12x16-in. open type rotary vane feeders spaced equidistantly along the 46-ft length of the bin. Each feeder is equipped with a rack and pinion cut-off gate and a sliding feed-regulating gate above the rotary vane. The feeders are driven by a 5-hp variable speed drive operating an eccentric that transmits a reciprocating motion through a shaft to ratchets on each of the feeders.

Crushing Plant Flowsheet



LEGEND

1. 7-ton Federal trucks
2. 90-lb rail spaced with 12-in. openings
3. 150-ton steel bin
4. One No. 5 Ross chain feeder
5. 36-in. conveyor belt with magnetic head pulley
6. Grizzly bars spaced with 1 3/4-in. openings
7. 18x36-in. Birdsboro-Buchanan jaw crusher
8. 300-ton steel circular ore bin
9. Two double acting reciprocating pan feeders
10. 60x126-in. Robins Eliptex vibrating screen, with 1/2x1/2-in. screen openings
11. 3-ft short head coarse bowl Symons cone crusher
12. Stephens-Adamson 18-in. shuttle conveyor
13. 600-ton steel suspension bunker bin (No. 1 of concentrator flowsheet)

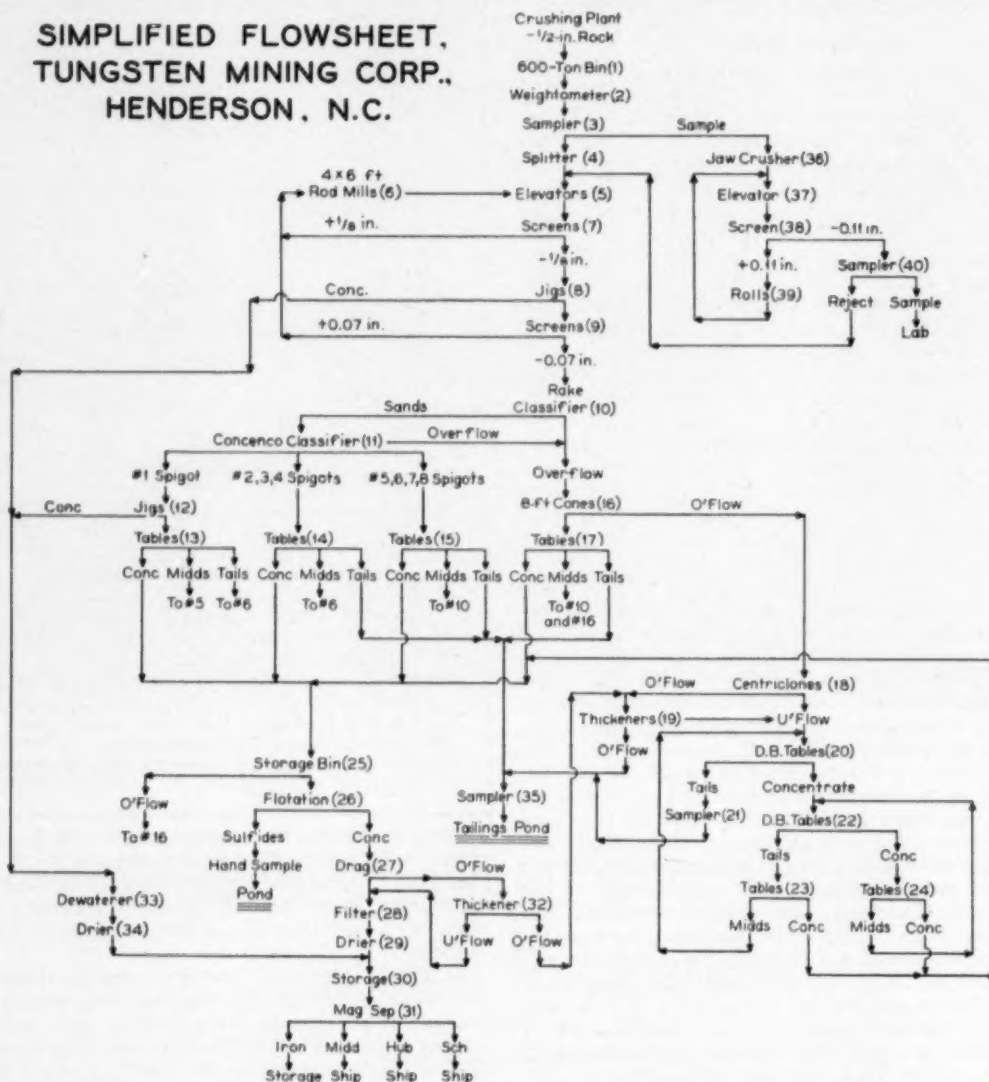
Two horizontal 20-in. conveyors under the rotary vane feeders carry the ore to a common chute under the center of the 600-ton bin where it is transferred to another 20-in. inclined conveyor traveling at 200 fpm. This conveyor has a Merrick type S Weightometer.

A Geary-Jennings automatic sampler located at the head pulley of the Weightometer belt cuts a sample of mill heads every 2 min. This sample is stored in a small steel storage bin. The sample is crushed and screened to 0.11 in. in a small sample mill consisting of a pan feeder, 3 small conveyors, a 4x6-in. laboratory jaw crusher, a set of 10x6-in. laboratory rolls, a 5-in. belt bucket elevator, a 14x36-in. Stephens-Adamson vibrating screen with 0.11-in. screen section, and another Geary-Jennings sampler. The final sample for each shift of about 25 lb of -0.11 in. material is sent to the assay laboratory in covered cans each morning.

Immediately following the first automatic sampler a splitter cuts the mill feed into two equal parts—one for each of the two independent grinding and sand concentrating circuits. After the feed is split, the two halves are fed to two 18-in. belt bucket elevators by two 20-in. belt conveyors. These elevators have a 40-ft lift and discharge onto two 4x8 Hummer screens, which are equipped with screen sections having 3/8-in. openings. Oversize flows by gravity to two 4x6-ft Marcy end peripheral-discharge rod mills. Ground products return by gravity to the two 18-in. belt bucket elevators closing the circuit with the 3/8-in. screens.

The - 3/8-in. products flow by gravity to four 36x36-in. Bendelari jigs operated in parallel. About 40 to 45 pct of the total tungsten mineral recovery

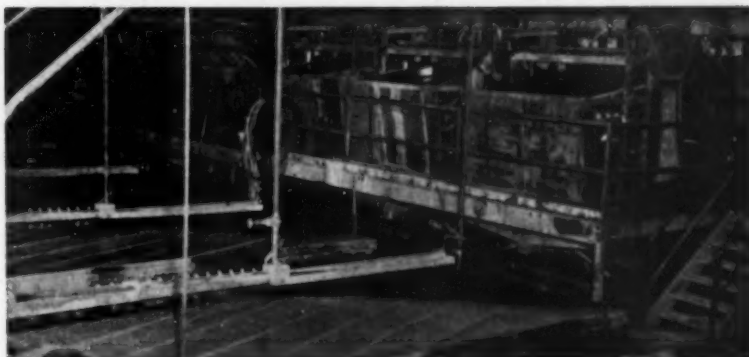
SIMPLIFIED FLOWSHEET, TUNGSTEN MINING CORP., HENDERSON, N.C.



LEGEND

1. One suspension bunker bin with 11 rotary vane feeders
2. One Merrick type S Weightometer
3. One Geary-Jennings automatic sampler
4. One stationary splitter—2 equal parts
5. Two 18-in. Belt Bucket Elevators—40-ft lift
6. Two 4x6-ft Marcy end peripheral-discharge rod mills
7. Two 4x8-ft Hummer screens with 1/8-in. openings
8. Four 36x36-in. Bendolari Jigs
9. Two 4x8-ft 3 section repulping Hummer screens with 0.07 in. Openings
10. Two 4x25-ft Denver rake classifiers
11. Two Concencho 8-spigot classifiers
12. Two 12x12-in. Crangle type Pan American pulsating jigs
13. One Deister No. 6 and one Wilfley No. 6 concentrating tables
14. Five Deister No. 6 and one Wilfley No. 6 concentrating tables
15. Six Deister No. 6, one Wilfley No. 6, and one Wemco concentrating tables
16. Four 8-ft cone classifiers
17. Four Deister No. 6 concentrating tables
18. Three 20-in. Centrifuges
19. One 20x10-ft and one 24x8-ft thickeners
20. Eight Denver-Buckman tilting deck tables
21. Geary-Jennings automatic sampler
22. Two Denver-Buckman tilting deck tables
23. Two Deister No. 6 concentrating tables
24. One Deister No. 6 concentrating table
25. One 8x8-ft steel storage bin
26. One 3-ft low-head Denver conditioner and 4 Denver No. 18 Sub-A cells
27. One Esperanza drag classifier
28. One 3x6-ft Dorco drum filter
29. One infra-red heat lamp drier
30. Two steel storage bins with two elevators
31. One Dings 6-pole high intensity, crossbelt magnetic separator
32. One 9x6-ft thickener
33. One spiral laboratory classifier
34. One infra-red heat lamp drier
35. One Geary-Jennings automatic sampler
36. One 4x6-ft laboratory jaw crusher
37. One 5-in. belt bucket elevator
38. One 14x36-in. Stephens-Adamson screen with 0.11 in. openings
39. One set of 10x6-in. laboratory rolls
40. One Geary-Jennings automatic sampler

Shown on the right are five of the ten Denver-Buckman tables in the center and background, with Deister slime tables in the foreground. Infra-red driers are visible at the right. Movement of concentrate is continuous from driers to sizing and storage prior to magnetic separation.



in the mill is made by the jigs. Hutch product and bed product flow by gravity to two 1-in. Wilfley sand pumps and to a dewatering cone. Cone underflow is fed to a 6 in. x 4 ft 6-in. dewatering laboratory spiral classifier. From the dewatering classifier the concentrate drops into an infra-red, screw conveyor, type drier. This drier has 80 lamps each 375 w and is capable of drying about 0.3 tph. Dried product discharges by gravity into a bucket elevator which discharges into a steel storage bin prior to magnetic separation.

Jig tailing flow by gravity to two 5-in. Wilfley sand pumps which discharge onto two 2-pan repulping 4x8-ft Hummer screens with openings of 0.07 in. Screen oversize flows to the same 4x6-ft rod mills as did the $\frac{1}{8}$ -in. material. Thus the ground 0.07-in. screen oversize returns by gravity to the 18-in. belt bucket elevators, which return it to the $\frac{1}{8}$ -in. screens, the jigs, and finally back to the 0.07-in. screens thus closing the circuit.

The -0.07-in. product flows by gravity to two 4-in. Wilfley sand pumps which discharge into two 4x25-ft Denver rake classifiers. The sand from the rake classifiers flows by gravity to two 8-spigot Conenco hydraulic classifiers. The first coarse sand spigot products flow to two 12x12-in. Crangle pulsating jigs. The tailing flows by gravity to the first sand tables of the two sand sections. The Crangle jig concentrate is combined with the other jig concentrate and dried. The other seven spigot products of the two classifiers flow by gravity to 14 sand concentrating tables, (11 Deister No. 6 tables, 2 Wilfley No. 6 tables, and 1 Wemco table).

The first sand table of each section produces a concentrate that is pumped to a steel storage bin ahead of the flotation unit, a sulphide middling returned by gravity to the elevator for rejigging, and a sand middling which is pumped back to the 4x6-ft rod mill for regrind. The 2nd, 3rd, and 4th tables of each section produce a concentrate which is pumped to flotation storage, a middling which is pumped to the 4x6-ft rod mill for regrind, and a tailing which is sampled and goes to waste.

The other four sand tables of each section produce a concentrate which is pumped to the flotation storage bin, a middling which is pumped to the rake classifier, and tailing which joins the other table tailings.

Overflow of the two rake classifiers and the two Conenco hydraulic classifiers form the feed for four 8-ft cone classifiers in parallel. Each cone underflow is fed to a Deister No. 6 diagonal deck concentrating table. Table concentrate is pumped to the flotation storage bin, the middling is returned to the rake

classifier in one section, and the cones in the other section, and the tailing joins the other table tailings.

The overflows from the four 8-ft cones of both the sand sections unite and go to three 20-in. Centriclones. The Centriclones are similar in principle to cyclones except that the centrifugal force is applied by an impeller built into the cone.

Underflow from the Centriclones contains about 90 pct of the +15 micron size particles and is fed to eight Denver-Buckman tilting deck tables. Each table has five 6x6-ft decks covered with flat dimpled rubber covers. The tables are fed with the decks at a low angle of slope for a period of about 6 min, the decks then tilt at a steep slope in the opposite direction at which time the decks are automatically washed clean with water sprays. The washing time is about 45 sec after which the decks return to the feed position and the cycle repeats.

The tailings from the eight tables flow by gravity to a Geary-Jennings automatic sampler, then to the main mill tailing launder through the main tailings sampler and to waste. The concentrate from these tables is pumped to a 10-ft cone the overflow of which returns to the Centriclones. The underflow is pumped to two Denver-Buckman cleaner tables which produce a concentrate to be upgraded on a Deister No. 6 slime table. The concentrate produced goes to flotation. Tailing from this upgrading table is returned to the cleaner tables. The tailing produced on the cleaners is recleaned on two Deister No. 6 slime tables which produce a concentrate for flotation, a middling for recleaning, and a tailing which is returned to the eight rougher tables.

Centriclone overflow, largely -15 micron particles, flows by gravity to a 20-ft and a 24-ft thickener which further remove solids which are pumped to the eight Denver-Buckman tilting deck tables to join the Centriclone underflow. These two thickeners were part of the slime section circuit of the mill prior to the expansion. Any one of the Centriclones may be by-passed using these thickeners to do the work of that Centriclone temporarily.

The flotation circuit consists of a storage bin with about 24-hr storage capacity, a 3x3-ft conditioner, and 4 Denver No. 18 Sub-A flotation cells. Flotation upgrading of the table concentrates is a bulk sulphide process and is done on a semibatch basis. The table concentrates as delivered to the flotation storage bin are about 25 to 30 pct sulphur and about 20 to 25 pct WO_3 . After flotation the concentrate runs 45 to 50 pct WO_3 , and about 3 pct sulphur. Sulphide product runs to about 0.05 pct WO_3 . Concentrate is dewatered in an Esperanza type classifier, the overflow of which is pumped to the 9x6-ft thickener.

Operating Figures

Product	Concentrate Distribution		
	Pct Weight	Pct WO ₃	Pct Dist. WO ₃
All Jig Concentrate	37	63.0	44
Table Conc. After Flotation	63	46.7	56
	100	52.7	100

Note: Concentrate dust production results from the crushing and handling of the jig and flotation concentrate.

4x6-Ft Rod Mill Liner and Rod Costs

	Consumption lb per ton	Cost—Cents per ton milled
Main Liners	0.187	0.42
Rods	0.808	5.23

Infra-red Heat Lamp Drier Costs

Power (lamps)	\$1.33
Power (drive)	0.03
Supplies	0.14
Labor (operation & maintenance)*	0.15
Total	\$1.65 per ton concentrate dried
* Estimated	

The thickener underflow is fed to the 3x6-ft Dorco filter along with the dewatered concentrate from the Esperanza classifier. The 9x6-ft thickener overflow goes to the 24-ft thickener outside the building.

The filter cake discharges directly into a duplex screw conveyor with 80 infra-red heat lamps 375 w each directly above the screws. The dried concentrate discharges into the same elevator as the jig concentrate with both concentrates being stored in a steel bin ahead of magnetic separation.

Two shifts each day the concentrate is fed to a 2x2-ft Hummer screen with a double screen section—one half has 0.09 in. sq openings and the other half has 0.02 in. sq openings. The two undersize products go to separate bins from which the magnetic separator is fed. The screen oversize is crushed in Sturtevant 8x5-in. laboratory rolls in closed circuit.

The magnetic separator is a Dings 6-pole, high intensity, crossbelt type machine. The first crossbelt removes an iron product, largely metallic iron, which contains about 5 pct WO₃. This is being stored until a market can be found or a process for upgrading can be worked out.

The second belt removes a middling product containing some metallic iron, sulphides, rhodochrosite, and some hubnerite which assays 15 to 20 pct WO₃, and is shipped for upgrading. The third, fourth, fifth, and sixth belts remove a high grade hubnerite concentrate. This runs from 70 to 73 pct WO₃. The end product which is nonmagnetic contains the scheelite, fluorite, and sulphides. This runs 15 to 20 pct WO₃ and is shipped for upgrading.

In conjunction with the magnetic separator and drying circuit a Pangborn bag-type dust collector is used. The dust collected from this circuit runs about 45 pct WO₃; it is sacked and shipped for upgrading.

The scheelite, middlings, and dust are all upgraded by chemical treatment to produce high grade artificial scheelite.

All of the concentrate shipments are made in 100 lb bags by truck. Final weighing is done at the time of shipment using platform beam type scales. A sample is taken from each sack of concentrate for production control and shipment control.

Some of the major improvements and circuit changes incorporated in the new crushing plant and milling plant are as follows:

Dust collection for the crushing and the dry portion of the milling plant is provided for by a Pangborn outdoor bag type collector. The screen, transfer points, and the crusher are all connected to the collector which is powered by a 40 hp motor. A motor-driven rapping mechanism is operated once each day to shake the dust into hoppers underneath the collector. These hoppers are discharged by rotary valves into a launder. Here the dust is washed by gravity into the fine sand tabling circuit via the 8-ft cone classifiers.

The former crushing plant, completely replaced by the new plant built beside it, is kept in stand-by condition for any emergency repairs that might cause lost milling time.

The new crushing plant has a capacity of 45 to 50 tph. This permits crushing on only two shifts a day. Two men are required each shift for operation of the crushing plant because of plant length, different floor levels, and large amount of scrap wood delivered with the ore. Ore contamination is caused by wood used for square-set stoping at the mine, and must be removed by hand from the belts prior to crushing.

Provision for stand-by grinding, screening, and jigging circuits is accomplished by using the 30-in. rolls and the 3x8-ft rod mill circuit which together formerly constituted the primary and secondary grinding circuit for the 300 ton mill. By installing two 4x6-ft Marcy end peripheral-discharge rod mills, an additional bucket elevator, and two sets of screens, jigs and pumps, three grinding, jigging and screening circuits are provided—any two of which will maintain full capacity of the milling plant. One of the elevators is capable of serving either the roll circuit or the adjacent 4x6-ft rod mill circuit, while the other elevator can serve either of the two 4x6-ft rod mills. This flexibility allows full tonnage to be maintained while maintenance or repairs are being performed on any one of the grinding, screening, and jigging circuits. Normal operation is with the two 4x6-ft rod mills handling the primary grinding, secondary grinding, and the middling regrind. The 4x6-ft mills are operated with dilute pulp, about 35 pct solids, to decrease retention time and prevent overgrinding. The hubnerite and scheelite are both quite friable and easily slimed, thus every effort is exerted to prevent sliming.

Stand-by pumps are utilized where vital to continuous operation. The feed may be switched from a pump in use to the stand-by pump without stopping the flow of the circuit or interrupting production. These stand-by pumps are utilized largely in the new sand section of the mill.

The slime section common to the two sand concentrating sections treats that portion of the pulp containing -200 mesh +15 micron particles. The Denver-Buckman tables are used to produce a low grade tailing and a concentrate for upgrading. The WO₃ assay of the tailing from this section of the mill is less than half that of the comparable tailing of the 300 ton mill.

Natural Gas, Industrial Water Keys to Intermountain Region Development

I. Industrial Water

by ElRoy Nelson

WATER provides to many mineral industries functions similar to those performed by money in the economic system. Water is a medium of exchange. It is also required in chemical reaction for cooling, for transfer of minerals, and for cleaning. To a great extent, water is also a raw material in almost every industrial operation; it becomes a component of the finished product.

In the Rocky Mountain region, water is treated with a great deal of respect. There has not been enough of it when needed. Long ago storage facilities were planned and devised to assure a supply during periods of shortages. This comes from the history of the region in irrigation and mineral processing. Within this region the shovel was always the most lethal weapon used in settling disputes over the use or misuse of water.

During this past summer, stories appeared almost daily of water shortages in most areas of the country. This applied most frequently to municipal water systems where wells had gone dry, where at the same time demand had increased. There have also been shortages within this region with attendant limitations on the use of water for lawn sprinkling. But, this has been common in many areas. In looking towards future demands, the Rocky Mountain region has been united in efforts to further develop and utilize the surface water supplies on the Colorado and other streams.

General Demand for Water

For production of crops within this region, annual use is from $\frac{1}{2}$ to 3 acre-ft of water per acre, varying as among crops, specific locations within the valleys,

ELROY NELSON is Vice President and Economist, First Security Corp., Salt Lake City.



and with altitude. Today, in this area, domestic use in the home seems to be based upon 3 $\frac{1}{2}$ acre ft with the increased per capita consumption since the close of World War II.

Industrial Uses

Within the past few years, increased attention has been given industrial water, both as to quality and

MINING ENGINEERING is pleased to publish in advance condensations of two papers to be given at the first Rocky Mountain Industrial Minerals Conference, Salt Lake City, Oct. 28 to 30, 1954. This conference, sponsored by the Industrial Minerals Div., AIME, gives every promise of becoming an annual feature in the roster of AIME fall meetings. The Utah Section is host.

quantity. New products, especially in the chemical fields associated with mineral processing, have increased the demand locally and nationally. In fact, selecting a plant site may be affected by both the quality and quantity of water available. Within this region, the site for Geneva Steel was determined, to some extent, by water availability.

Today's management in expanding, in remodeling, or in locating new operations, usually looks to water supply. But considerably more attention can be given this problem. In most mineral processing, water must be transported to the site of industrial operation. In other instances, the raw material such as natural gas or petroleum, can be transported to the water.

A few comparisons illustrate the tremendous demand for industrial water in this area.

Kennecott Copper. This company's daily use approximates 80 million gal of water. Three fourths of this is used in the mills in connection with flotation operations. Of water used in the mills, there is no serious problem of quality; but water used in the power plant for steam must be treated. The quantity comparison is of greatest interest. Kennecott Copper's demand is almost equal to the total average daily demand of Salt Lake, Ogden, Logan, and Provo municipal systems.

Geneva. This plant reached the following demand totals: untreated water, 23 million gal; treated, 204 million gal. This, however, is the total that flows through the pipes during the day. Actually, most of the treated water is used and reused. Water used has reached 30 million gal as against a total circulation of 237 million gal. This amount circulated has, at peak production, approximated the total circulating systems of Denver and Salt Lake City. Most of the water at Geneva is from shallow wells, supplemented by water from Deer Creek and new possible sources from deep wells.

Oil Refining. Two major oil companies in the Salt Lake area use 4.5 million gal of water per day. Of this total, approximately 3 million gal are purchased from Salt Lake City; 2 million gal are from wells. Water from wells is used primarily for cooling purposes, has a high mineral content, and is usually untreated. Water purchased from Salt Lake City is used for other phases of oil refining. The total water consumption per day at the two refineries, counting both well water and purchased water, is one twelfth as great as that used in Salt Lake City.

Power Generation. Steam electric plants constitute another major use of water. The new expansion near Salt Lake City has increased further the demand for water up to one half million gal per day.

As nearly as can be determined, no industrial development such as a new plant or an expanding plant operation has been discouraged in this area because of lack of water. There is no guarantee that this will continue. The recent announcement of a chemical plant to produce anhydrous ammonia in the area points to additional demand for water. From anhydrous plants located elsewhere in the nation comes this figure: up to 46 gal of water are required to produce 1 lb of anhydrous. At the announced daily production of 120 tons, approximately 11 million gal of water, or one fifth the total demand of Salt Lake City would be required. However, much of this water could be reused.

Over the past few years, a number of surveys have been made to determine the quantity of water used to produce given quantities of products. There

is considerable lack of agreement among these various reports, depending to a great extent upon the sources of data. To avoid debate, the list below is taken from just one source.

Quantities of Water Used in Producing 1 lb of Final Product

Product	Gallons of Water
Synthetic Ammonia	46
Hydrofluoric Acid	42
Acetic Acid and Acetylene	
Phosphoric Acid (Blast Furnace)	37
Liquid Oxygen	21
Calcium Carbide	15
Beet Sugar	14
Beer	12
Liquid Sulphur Dioxide	9
Ethyl Alcohol (via molasses)	8
Soda Ash (via Solvay)	8
Pig Iron (blast furnace)	6
TCC gasoline	4.75
Ammonium Sulphate	2.5
Rock Wool	2
Hydrochloric Acid—using salt	1.5
Electric Furnace Phosphorus	1.5
Ammonium nitrate	1.3
Sodium Hydroxide (via lime soda)	1.2

Source: adapted from *Chemical Engineering*, April 1951, p. 111

Quality of Water

Ideal water for most industrial use would be one of zero mineral content, or water of distilled quality. This quality, if ever, is rarely achieved, because there are suspended mineral impurities, insoluble matter, and bacteriological contamination in almost all water. Theoretically, rain water could answer the question, but dissolved gases from the atmosphere are found in this water. In fact, rain water sometimes has a hardness of 43 parts per million. In almost all the West, surface water hardness varies from 8 to about 50 parts per million. The problems of alkalinity, temporary or permanent hardness, are problems for specific areas and industries.

Pumping is another problem. Generally, 1 kw-hr is required for each 1000 gal pumped. The cost of pumping at 5 mills per kw-hr is \$10,000 per year for 10 million gal. At 1¢ per kw-hr, the cost would be \$20,000 per year. Quantity of water available may determine whether or not the water would be reused, and the pumping expense incurred.

With increasing importance of nonmetallic minerals and various chemical processes, water becomes of greater importance. This region is looking at the mineral chemical industries and the salts from brines of Great Salt Lake or from wells. It is also looking at additional petroleum and coal and gas chemical industries. To add to the metals industries, it is eyeing various other nonmetallic minerals. These require water—water in quantities—and of a given softness. Water may be a major site factor—at least a major cost factor. In plans for expansion too, water is of increasing importance and plans for financing must consider this item.

II. Natural Gas in the Intermountain Area

by H. F. Hillard

NORMALLY, gas is not thought of as a mineral, yet it is a natural resource which must be discovered, developed at considerable expense and conserved in order to bring all of its benefits to mankind. For the past 25 years it has played an important role in the changing economy of the Intermountain area. It is providing industry with a competitive source of energy and residential users with a clean, low priced, automatic fuel.

In this Intermountain area lies the Great Salt Lake Valley. Here are the industrial centers of Ogden, Provo, and Salt Lake City, serving as the hub of the area's business activities. Within this industrial area is a concentration of about 425,000 people representing one third of the population of the entire Intermountain region. This Salt Lake Valley together with a few towns in southwestern Wyoming are the present markets for natural gas produced from nearby fields.

There are four gas producing areas in the Intermountain region. First, there is the Green River Basin in southwestern Wyoming, lying generally north of the Uinta Mountains and centering around the Baxter Basin gas fields. This basin touches the northeast corner of Utah and the northwest corner of Colorado.

Then there is the recently recognized Wasatch Plateau, a high mountainous area in central Utah, extending south some 70 miles from Spanish Fork canyon. The Clear Creek field lies in the northern part of this plateau. Next, the Uinta Basin is that area in northeastern Utah lying immediately south of the Uinta Mountains. It extends from the Wasatch Mountains on the west, well into the foothills of the Rocky Mountains in Colorado to the east. Last, is the San Juan Basin in the Four Corners area of Arizona, New Mexico, Colorado, and Utah.

The Green River Basin is of most importance to the people of the Salt Lake area because for 24 years it provided all of their gas supply and since last year about three quarters of it. These Green River gas fields are generally small in size. The producing sands are normally located at depths from 2000 to 6000 ft and with initial gas pressures from 1000 to 2500 psi. A notable exception to these conditions is the large Church Buttes field in the Wyoming portion of the basin. Here the producing sands are at a depth of 13,000 ft with an initial pressure at the well head of about 5400 psi. Production in the Green River Basin comes from a dozen fields in which more than 50 separate distinct gas reservoirs can be counted. This is in sharp contrast to gas fields like Hugoton in southern Kansas or the Texas Panhandle area where trillions of cubic feet of gas reserves can be measured in one continuous reservoir extending many miles.

The Wasatch Plateau is the scene of a great deal of exploration today. Several recent gas discoveries have been made, but so far the only gas brought to the Intermountain market comes from the relatively large Clear Creek field west of Price, Utah.

H. F. HILLARD is Chief Engineer, Mountain Fuel Supply Co., Salt Lake City.



At present, no gas from the Uinta Basin or the San Juan Basin reaches the Salt Lake area.

All gas served to the Intermountain market is distributed through the facilities of Mountain Fuel Supply Co. Natural gas was first brought into the Salt Lake Valley in September of 1929 from the fields of the Green River Basin through a long transmission line.

Branch or tap lines feed a few towns in Wyoming and Utah along the way. The main line with subsequent additions provides gas to customers now totaling about 110,000. The gas supplied to the valley came entirely from the Green River Basin until last year when the Clear Creek field was connected to the Mountain Fuel system near Orem, Utah.

Growth was slow during Mountain Fuel's early years of operation, but since World War II the demand for natural gas has expanded at a remarkable rate, spurred by rising prices among competing fuels. To provide for this demand, the field production and the transmission capacity into the valley have increased until they are now 235 million cu ft per day or four times the gas supply of the original project. Over the years, natural gas has become firmly established as a highly desirable, economical fuel for both residential and industrial purposes.

Exploration for gas has been pushed vigorously during the last 25 years because of the ever-growing demands of the Salt Lake Valley. Mountain Fuel began its operations with a proven gas reserve of 220 billion cu ft. Today, after 25 years of production, the reserves dedicated to the Intermountain market are more than 1.2 trillion cu ft, an amount which will last in excess of 20 years at the present rate of withdrawal.

It appears that there are excellent prospects for continuing growth of the gas industry in this area, although there is the problem of finding the additional gas reserves. There is still a considerable acreage in the Intermountain region which has not been fully explored, and many large oil and gas companies are engaged in exploration and wildcat drilling on the most promising structural areas in the region. Even though the ratio of successes in wildcat ventures of this type is only about one out of nine, the abundance of activity may be expected to result in substantial increases in the gas reserves of the Intermountain area.

Statistical Analysis Points the Way For \$\$\$\$ Savings in Beneficiation

by A. C. Dorenfeld

CHANGES in circuits are often made in milling operations. At the same time that these changes are being evaluated the ores are changing. Even from the same mine, the ore is usually variable as to amount and type of mineral content, degree of association of valuable and gangue minerals, amount and types of soluble salts, hardness, etc. The question then arises whether any small differences in results, after changes have been made in the various circuits, are really due to these changes or whether the variability of the ore can account for those differences.

Statistical evaluation provides one method of answering the question that arises so often in beneficiation studies: Did changed results come about because of changed process, or did ore variation cause the change? In this case, data were available for statistical analysis from an operating period of 42 months, representing treatment of approximately 1 million tons of ore. During this period there had been two flowsheet changes: 1) regrind of the zinc circuit middlings was introduced, and 2) alcohol-pine oil frother mixture was substituted for cresylic acid-pine oil frother mixture. Findings are in Table I.

The operation is a 1000-tpd lead-zinc sulphide flotation plant, using standard treatment procedures. Ore is extremely variable as to mineral content, mineral association, hardness, and the amount and

A. C. DORENFELD is Associate Professor of Mineral Engineering, School of Mines, University of Alabama.

probably, the nature of soluble salts. Metal content of shift head samples varied from 16 pct to as high as 50 pct combined valuable mineral, and averaged about 40 pct.

Mineral association varied from fine grained combinations which could not be completely liberated at 600 mesh to relatively coarse grained combinations liberated at about 200 mesh. The pH samples from various stopes did not seem to be a criterion as to whether the minerals would separate well or not. Gangue was ordinarily hard silicified cherty rock, but sometimes was soft limestone, and occasionally rhodochroite and rhodonite. At times the ore was partly oxidized and limonitic.

Statistical Evaluation When Ore Varies

It is an axiom in milling that the grade of feed in some measure determines the per cent recovery, and the grade of the concentrate. If this is true, then to compare results from one month with another there would have to be almost identical feed grades. The ore under consideration was so variable that this was rarely true. Thus, to compare monthly results one must first prove that variation of zinc head grade does not affect zinc recovery or zinc concentrate grade.

Curves showing zinc head grade, zinc concentrate grade, and per cent zinc recovery, in the graphs, approach a normal distribution in form. Therefore the normal distribution and "t" distribution equations can be used statistically without serious error, since it has been shown by Camp³ and Meidell,⁴ that

Definition of

ance.¹⁶ It is given by the formula:

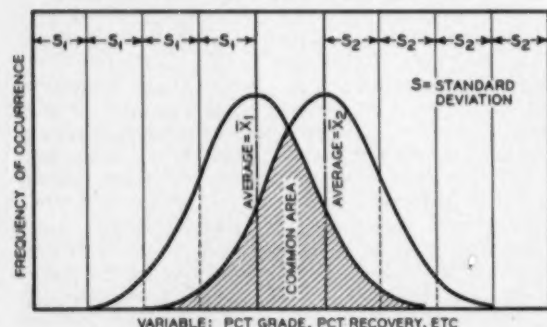
$$\text{standard deviation} = S = \sqrt{\frac{\sum X^2}{n} - \bar{X}^2} \quad [1]$$

where: $\sum X^2$ = the sum of the squares of each individual term of the data

n = number of individuals in the data

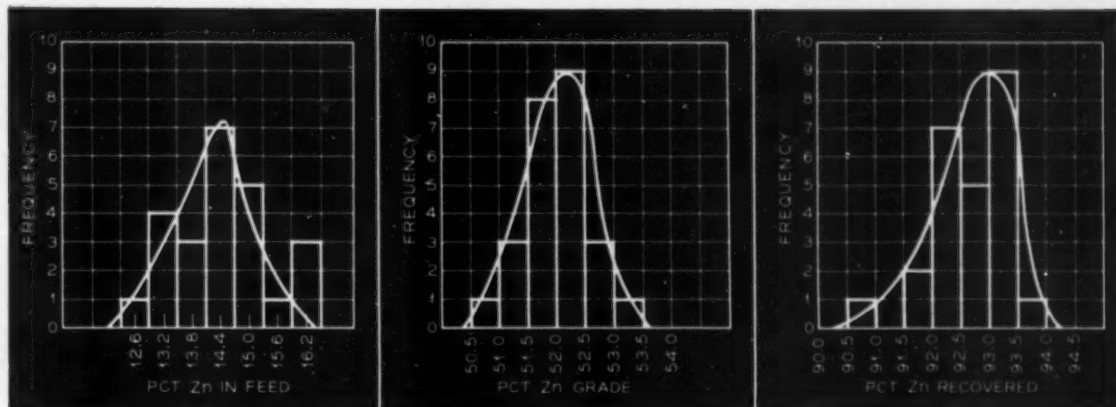
\bar{X} = the average of the data

1. **Normal distribution** is a mathematical distribution made up of individuals perfectly described by knowing the average and standard deviation of these individuals, see the diagram below.



2. **Mean or average** is the line which divides a distribution area in exactly equal parts, see diagram. It is the moment of the data about the origin.¹⁷
3. **Variance** is a measure of variation of the data about the mean. It is the second moment of the data about the mean.¹⁸
4. **Standard deviation** is the square root of the vari-

5. **Population** is the infinite number of tests that could be made using one particular physical condition. The greater the number of tests the closer the approach is to the population. The mean of the population is denoted by m , and the standard deviation by σ .
6. **Sample** is a finite number of tests, N , drawn at random from a population. Each sample will have its standard deviation, S , and average \bar{X} .
7. **Significance level** is the risk taken in being wrong. Thus a significance level of 5 pct means that in the long run the conclusion may be wrong 5 times out of 100 times. It is usually fixed by the economics of the situation. If large scale costly additions would be necessary to install a new process, then a significance level of 1 pct or better would be justified; if the new process is merely a change



Curves of zinc head grade, zinc concentrate grade, and per cent zinc recovery (shown above) approach a normal distribution in form. Therefore, the normal distribution and "t" distribution equations can be used statistically without serious error.

under similar circumstances, the maximum error, at 3σ limits, cannot be greater than about 5 pct.

Statistically, the method involves the use of correlation coefficients and partial correlation coefficients. These terms are described in the Definition of Terms and more detailed information is provided in the references.^{10,11} Partial correlation coefficients and levels of significance for the data from the lead-zinc operation are summarized in Table II.

A comparison of the reliability, Z, and the significance level reveals the variation of zinc content in the feed in this case does not significantly affect zinc concentrate grade or per cent zinc recovery. Any significant variation in the two latter quantities, when something is changed in the zinc circuit, cannot be ascribed to change of feed grade, provided grades are within the limits used for the comparisons in Table II.

Analysis of Process Changes

Zinc section results are summarized statistically

in Table III. First consider the concentrate grades: Per cent area in common for two distributions is, for a small number of samples, the area corresponding to the "t" in distribution tables. Substituting in equations [2] and [3] one obtains a comparison of (1) and (2) in Table III:

$$t = \frac{53.055 - 52.045}{\sqrt{25 \times (0.595)^2 + 10 \times (.769)^2}} \sqrt{\frac{25 \times 10 (25 + 10 - 2)}{25 + 10}} = 4.04$$

$$\text{and } v = 25 + 10 - 2 = 33$$

Entering the probability tables¹² at $v = 33$, and for a value of "t" = 4.04, the probability that the means come from similar processes is less than 1 pct. Thus it is 99 pct certain that regrind results are different than the results without regrinding. The 1 pct increase in grade was definitely due to regrinding.

Other comparisons are summarized in Table IV. Comparison of 1(a) and 1(b) shows that the grade of concentrate was definitely increased 1 pct, but

Statistical Terms

in reagents, of substantially equal costs, then a significance level of perhaps 20 pct might be justified.

8. **"t" Distribution** is the distribution of samples consisting of a small number of observations.¹⁴ It is similar in nature to the normal distribution.
9. **Comparison of Means of Distributions.** The diagram shows two distributions with different means. If a certain significance level (Definition 7) is accepted, then the per cent area common to these distributions must be less than the significance level.¹⁵ Tables for these areas exist,¹⁶ giving the per cent common area corresponding to "t" and v , where

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{n_x S_x^2 + n_y S_y^2}} \sqrt{\frac{n_x n_y (n_x + n_y - 2)}{n_x + n_y}} \quad [2]$$

$$v = n_x + n_y - 2 \quad [3]$$

Where: n_x = number of observations in Sample x
 n_y = number of observations in Sample y
 S_x = standard deviation of Sample x
 S_y = standard deviation of Sample y
 v = degrees of freedom

10. **Correlation Coefficient** is a measure of the utility

of a straight line in estimating the relationship between two variables. The correlation coefficient between variables x and y is written as r_{xy} . Correlation coefficients can only lie between -1 and +1. The nearer they are to either -1 or +1, the stronger the linear relationship between variables. Formulas for calculating r_{xy} have been developed.¹⁷

11. **Partial correlation coefficient** is similar to (10) except that the relationship is between two variables, holding other variables constant mathematically. The partial correlation coefficient between x and y, holding z constant is written as $r_{xy.z}$. Methods exist for calculating these coefficients.¹⁸

12. **Reliability of correlation coefficient** is tested as follows: The standard deviation is $\sigma_r = 1 / \sqrt{n - m - 3}$ where: n = number of samples
 m = number of variables held constant mathematically.

The correlation coefficient r , is substituted in the following formula, without regard to sign:

$$Z = \frac{1}{2} \log e \frac{1+r}{1-r}$$

if $Z > 3\sigma_r$, then variable x is related to variable y, with a 99.7 pct certainty. The mathematics has long been known and used.⁹

that the zinc recovery was substantially the same. Comparisons 2(a) and 2(b) show that thickening the middling prior to regrinding results in some loss of recovery, (90.79 pct Zn vs 91.86 pct Zn, see Table III) with no significant increase in grade of concentrate. Comparisons 3(a) and 3(b) indicate a possibility that the grade of concentrate may be lower with the alcohol-pine oil frother, (52.347 pct Zn vs 53.055 pct Zn, see Table III), but the recovery is higher, (91.767 pct Zn vs 90.790 pct Zn, see Table III). Conclusions based on comparisons 3(a) and 3(b) are on less certain ground: 20 pct and 28 pct

Table I. Mill Data, Monthly Averages

Month No.	Heads of Zinc Section ¹		Concentrate	
	Pct Zn	Pct Zn	Zn Recov., Pct ²	
1	13.87	52.97	92.24	
2	14.21	51.90	92.54	
3	14.78	51.73	93.38	
4	13.24	51.15	92.13	
5	14.68	51.94	92.77	
6	13.84	51.89	93.68	
7	14.19	51.33	93.11	
8	14.23	52.03	93.38	
9	14.11	52.23	93.34	
10	14.98	53.03	92.43	
11	13.65	52.44	91.96	
12	13.68	52.21	92.49	
13	13.41	52.23	92.55	
14	13.38	52.80	92.23	
15	12.70	51.81	92.20	
16	14.21	51.77	92.17	
17	18.06	52.14	92.55	
18	15.01	52.22	91.89	
19	14.25	51.98	93.36	
20	14.58	52.50	93.40	
21	13.34	51.29	93.40	
22	15.98	52.01	93.22	
23	16.31	50.76	92.70	
24	16.27	52.19	93.25	
25	16.29	51.58	90.88	
26*	16.69	53.28	92.17	
27*	16.31	53.70	92.16	
28*	14.77	51.00	91.24	
29**	14.83	52.97	89.43	
30	14.57	51.77	89.43	
31	13.76	53.12	90.54	
32	13.96	54.76	92.78	
33***	13.34	52.79	91.79	
34	12.73	52.95	90.75	
35	14.78	52.57	90.57	
36	15.38	52.22	90.33	
37	14.37	53.49	90.75	
38	13.57	53.52	91.41	
39	15.08	53.19	91.91	
40****	15.34	51.99	92.54	
41****	15.19	51.82	91.17	
42****	14.04	53.23	91.59	

* Regrind of Zn middlings without thickening.
 ** Regrind of Zn middlings with thickening for all succeeding months, except No. 33.
 *** No regrind of Zn middlings for two weeks in this month.
 **** Frother changed from cresylic-pine oil mixture to alcohol-pine oil mixture.
 † Calculated.
 ‡ Zn recovery as pct of Zn in Zn section.

Table II. Partial Correlation Coefficients Zinc Section

Data: Months 1-25-No Middling Regrind				
Relation-ship	Partial Correlation Coefficient	$Z = \frac{1}{2} \ln \frac{1+r}{1-r}$	1 Pct Sig. Level $3\sigma_{\sigma Z}$	Significance
12.3	-0.205	0.503	0.06	Related by chance
13.2	0.279	0.289	0.06	Related by chance
23.1	0.632	0.744	0.06	Better than 99 pct certain that a relationship exists.

Where: variable 1 = Zinc Head Grade
 variable 2 = Zinc Concentrate Grade
 variable 3 = Zinc Recovery, per cent.

$$\sigma_Z = \frac{1}{\sqrt{25-1-3}} = 0.22$$

Table III. Mean and Standard Deviations for Zinc Section Four Different Operation Conditions

Method of Operation No.	Months of Operation N	Mean Grade \bar{X}_1 Pct Zn	Standard Deviation S_1 Pct Zn	Mean Recovery \bar{X}_2 Pct Zn	Standard Deviation S_2 Pct Zn
(1) No regrind	25	52.045	0.595	90.560	1.451
(2) Regrind & thickening	10	53.055	0.760	90.790	0.981
(3) Regrind, no thickening	3	52.960	0.760	91.860	0.361
(4) Regrind & thickening and frother alcohol-pine oil	3	53.347	0.80	91.767	0.518

Table IV. Comparison of Means (a) Zinc Concentrate Grade

Comparison Number	Method of Operation I	Method of Operation II	t	Degrees of Freedom	Probability Means Are Alike, Pct
1)	No regrind	Regrind and thicken	4.04	33	Less than 1
2)	Regrind & thicken	Regrind, no thickening	0.173	11	90
3)	Regrind, thicken, cresylic-pine oil frother	Regrind, thicken, Alcohol-pine oil frother	1.34	11	20

(b) Per cent Zinc Recovery

Comparison Number	Method of Operation I	Method of Operation II	t	Degrees of Freedom	Probability Means Are Alike, Pct
1)	No regrind	Regrind and thicken	0.447	33	64
2)	Regrind & thicken	Regrind, no thickening	1.698	11	12
3)	Regrind cresylic-pine oil frother	Regrind alcohol-pine oil frother	1.170	11	28

probabilities respectively. This would indicate that more data are necessary before a conclusion with 10 pct or less uncertainty (over 90 pct probability) could be obtained.

At the time this work was undertaken there was disagreement as to whether the 1 pct increase in grade zinc concentrate was actually due to regrinding. A 1 pct increase in grade was worth approximately \$100 per day, and the statistical method described here helped prove the value of regrinding.

Unfortunately, reserves of lead-zinc ore have become low at this mine, and the mill has been reduced to treating lead-zinc ore only once a week, which has not provided opportunity for extension of this work.

These methods, so far as the author knows, are not being used on a regular basis in milling—and that situation is the reason this article was written—to stimulate both thought and action in applying available mathematical tools to analysis of complicated metallurgical data.

References

- ¹ P. G. Hoel: *Introduction to Mathematical Statistics*, p. 8, Wiley; ¹² p. 11; ¹³ p. 67; ¹⁴ p. 143; ¹⁵ pp. 145-46; ¹⁶ p. 248; ¹⁷ p. 85; ¹⁸ pp. 110-120.
- ¹⁹ R. A. Fisher, *Statistical Methods for Research Workers*, 7th. Ed. pp. 212-203, Oliver and Boyd.
- ²⁰ B. H. Camp: *A New Generalization of Thebycheff's Statistical Inequality*, Bull. of the Am. Math. Society (1922) vol. 28, pp. 427-432.
- ²¹ M. B. Meidell: *Sur un problème du calcul des probabilités et les statistiques mathématiques*. Comptes Rendus (1922) vol. 175, pp. 806-808.

Safety Factor Characteristic Curves

by W. A. Boyer

Their Application to Mine Hoisting Ropes

If the safety factor of a mine hoisting rope is checked for the lowest depth, is the rope then safe for all levels? The answer here is no. A new set of values is proposed.

HOISTS for metal mines are seldom designed for one particular depth. They are intended for an ultimate load and depth with a given speed but are first used to hoist from a shallower depth, gradually working to the ultimate as development progresses. Sometimes the mine is not worked on the upper levels because of the kind and grade of ore, the mining of which depends on market conditions. In this case the hoist may be used in the same working shift to lift ore, for example, from the 1200 and the 4400-ft level.

This means that the safety factor of the rope should be considered not only when it hoists from the greatest depth, but also when it hoists from the upper levels. According to present safety factor standards, a hoisting rope can have ample safety margin when hoisting from the lower or lowest level and still be shy of sufficient safety margin when hoisting from the upper levels. This will be shown by curves presented in this paper.

The safety factor of a hoisting rope as defined by the U. S. Bureau of Mines¹ is the ratio of the static load to the tensile strength of the rope. It is calculated by dividing the breaking strength of the rope*

* As stated by the manufacturer or as determined by testing.

by the sum of the maximum weights to be hoisted, including the weight of the skip or car, the weight of the material to be hoisted, and the total weight of the rope when it is extended to the bottom of the shaft. The safety factors recommended by the U. S. Bureau of Mines are presented in Table I.

W. A. BOYER, Member AIME, is Superintendent, Mechanical and Electrical Depts., Northwest Mining Div., American Smelting & Refining Co., Wallace, Idaho.

Discussion on this paper, TP 3875A, may be sent (2 copies) to AIME before Dec. 31, 1954. Manuscript, March 25, 1954. Meeting Northwest Mining Assoc., Spokane, Wash., Dec. 5, 1953.

In Fig. 1 curves A and B are plotted against the vertical suspended distance, which is the abscissa, and the factor of safety, the ordinates. Curve C is a smooth curve drawn through the midpoints of the steps of curve A and would more closely represent the minimum factor of safety for new rope for any particular depth. Curve D is a smooth curve drawn through the midpoints of the steps of Curve B and would more closely represent the minimum factor of safety when ropes should be discarded for any particular depth. If a new rope were applied with a minimum factor of safety, then the vertical distance or ordinate under curve D for any particular depth, divided by the vertical distance or ordinate under curve C, would represent the minimum percent of remaining area intact that could be allowed before the rope would be discarded.

Table I. Hoisting Rope Safety Factors As Defined by the U. S. Bureau of Mines

Length of Rope, Ft	Minimum Factor of Safety for New Rope	Minimum Factor of Safety When Rope Must Be Discarded
500 ft or less	8	6.4
500 to 1000 ft	7	5.6
1000 to 2000 ft	6 (curve A)	5.0 (curve B)
2000 to 3000 ft	5	4.3
3000 ft and more	4	3.6

Also, that section of the ordinate between curve C and curve D is proportional to the section of the area of the new rope that could be allowed for wear and broken wires. Considering that point at 2500 ft on the chart, the ratio d_0 to c_0 would be the minimum percent of rope area remaining at the point of discard. The ratio of that portion of the ordinate d_0 to c_0 would represent maximum percent of area of a new rope available for wear and broken wires.

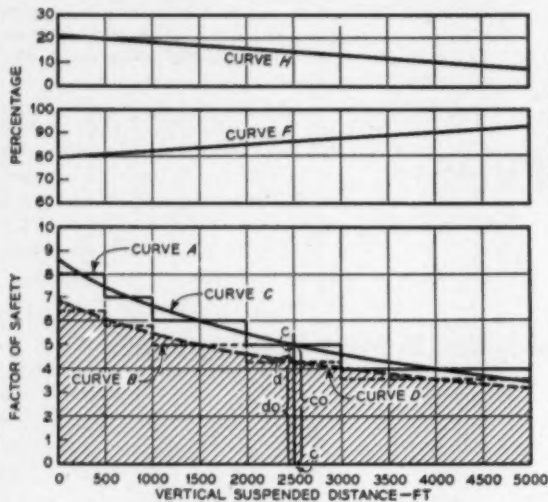


Fig. 1—A study of old factor of safety standards with ropes calculated for the maximum loading or the minimum factor of safety.

Curve A—Minimum factor of safety for new rope (U.S. Bur. Mines).
 Curve B—Minimum factor of safety when rope must be discarded (U.S. Bur. Mines).
 Curve C—Smooth curve drawn through midpoints of steps of curve A.
 Curve D—Smooth curve drawn through midpoints of steps of curve B.
 Curve E—Minimum percent of remaining area intact at point of discard.
 Curve F—Maximum percent of area of new rope available for wear and broken wires.

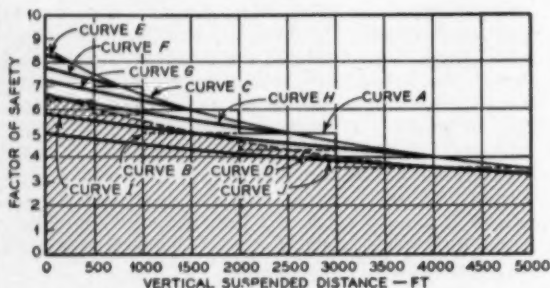


Fig. 3—Comparison of old safety factor curves with characteristic curves of modern rope with various loadings. Shaded area is that portion below curve D when rope must be discarded, present standard.

Static loading: $1\frac{1}{4}$ -in. improved plow steel rope. Weight of rope, lb per ft: 2.50. Breaking strength: 64.6 tons or 129,200 lb. Acceleration rate: 0.

Curve A—Minimum factor of safety for new rope, old standard.
 Curve B—Minimum factor of safety when rope must be discarded, old standard.
 Curve C—Curve drawn through midpoints of steps of curve A.
 Curve D—Curve drawn through midpoints of steps of curve B.
 Curve E—Characteristic curve for $1\frac{1}{4}$ -in. improved plow steel rope at maximum loading, 250 ft.
 Curve F—Characteristic curve for $1\frac{1}{4}$ -in. improved plow steel rope at maximum loading, 750 ft.
 Curve G—Characteristic curve for $1\frac{1}{4}$ -in. improved plow steel rope at maximum loading, 1500 ft.
 Curve H—Characteristic curve for $1\frac{1}{4}$ -in. improved plow steel rope at maximum loading, 2500 ft.
 Curve I—Characteristic curve for $1\frac{1}{4}$ -in. improved plow steel rope at maximum loading, 4000 ft.
 Curve J—Characteristic curve for rope of curve I when ready for discard under requirements of old standard.

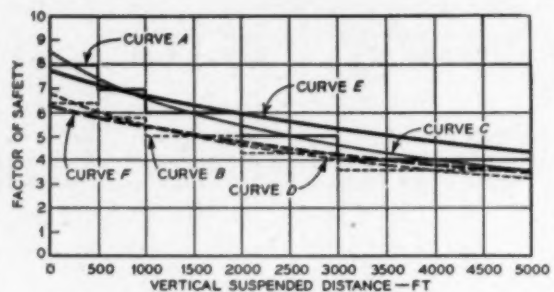


Fig. 2—Comparison of old factor of safety values and new proposed factor of safety values.

Curve A—Minimum factor of safety for new rope, present standard.
 Curve B—Minimum factor of safety when rope must be discarded, present standard.
 Curve C—Smooth curve drawn through midpoints of steps of curve A.
 Curve D—Smooth curve drawn through midpoints of steps of curve B.
 Curve E—Minimum factor of safety for new rope, new proposed standard.
 Curve F—Minimum factor of safety when rope must be discarded, new proposed standard.

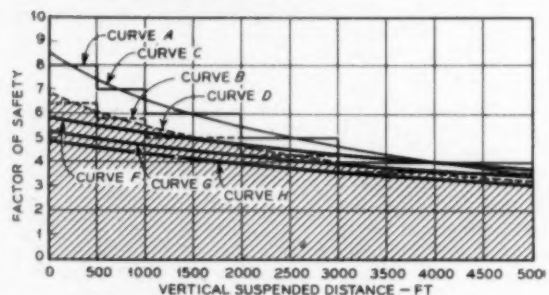


Fig. 4—Comparison of an actual rope safety factor characteristic curve with U. S. Bureau of Mines values. In this instance the rope is loaded under static conditions to the value of 4 at 4000 ft. Shaded area is that portion below curve D when rope must be discarded.

Weight of skip, cage, and ore: 22,200 lb. Size of rope: $1\frac{1}{4}$ in. Grade of steel in rope: improved plow steel, 6x10. Weight of rope, lb per ft: 2.50. Breaking strength of rope: 64.6 tons or 129,200 lb.

Curve F—Acceleration: 0, static loading.
 Curve G—Acceleration: 0.10 g or 3.216 ft per sec per sec.
 Curve H—Acceleration: 0.30 g or 9.432 ft per sec per sec.

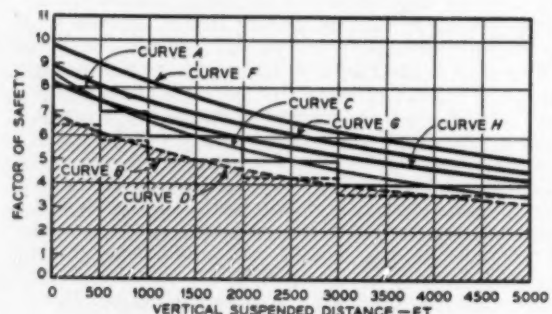


Fig. 5—Compare with Fig. 4. Shaded area is that portion below curve D when the rope must be discarded.

Weight of skip, cage, and ore: 13,206 lb. Size of rope: $1\frac{1}{4}$ in. Grade of steel in rope: improved plow steel, 6x10. Weight of rope, lb per ft: 2.50. Breaking strength of rope: 129,200 lb.

Curve F—Acceleration: 0, static loading.
 Curve G—Acceleration: 0.10 g or 3.216 ft per sec per sec.
 Curve H—Acceleration: 0.30 g or 9.432 ft per sec per sec.

If these ratios for the different depths are worked out and plotted, curve *F* represents the minimum percent of remaining area intact at point of discard for any particular depth, and curve *H* the maximum percent of area of the new rope available for wear and broken wires. Checking these curves reveals that the factor of safety schedule as set up allows for a 10 pct loss of area of the new rope to cover wear and broken wires at 4500 ft and would allow a 20 pct loss of area of the new rope to cover wear and broken wires at 250 ft. By the above standards the point of discard of a given rope would be determined by the allowable percent for wear and broken wires for the greatest depth from which the rope works.

Curves *C* and *D* of Fig. 1 do not follow along the characteristic curve of any rope of modern construction used for hoisting purposes. They do exactly coincide with the characteristic curve of a 1¼-in. mild steel rope having a breaking strength of 75,000 lb.** The characteristic curve of the present 1¼-in.

** Such a rope was listed in a manufacturer's catalogue of 1913.

plow steel rope, which has a breaking strength of 129,200 lb, is much flatter when loaded for the safety factor values used here.

It is here proposed that new safety standards be set up governed by the characteristic curve of a rope of modern construction and material. It is also suggested that a 20 pct reduction of effective area of the rope be allowable at all depths for wear and broken wires. On the basis of these new standards a pound loading can be given for each size of rope which automatically will take care of the safety factor requirements. Table II shows the old and the new proposed values for the factor of safety for various depths. The old values given are taken from curves *C* and *D* as being more comparable.

Old and new values for the factor of safety are plotted in Fig. 2. It will be noted that above 900 ft the old values are higher than the new but that below 900 ft the new values become increasingly higher with increase in depth.

In Fig. 3 curves are plotted for 1¼-in. improved plow steel rope according to the old factor of safety standards and according to the new standards providing an allowable factor of safety for the various maximum depths as indicated. Perhaps no greater proof is needed of the inadequacy of the older method. In all cases the rope characteristic curve is much flatter. Take, for example, the rope calculated for 4000 ft, curve *I*. The new rope would not fulfill the factor of safety requirements for a rope to be discarded above the 1500 ft point. Curve *J* is the characteristic curve for the rope of curve *I* with a reduction of effective area of 10 pct or for the point of discard at 4000 ft. This allows the use of a rope for depth which falls far short of fulfilling the factor of safety requirements for the shallower depths. The author cannot see that the present standards are accomplishing their aim when such conditions are possible. If the engineer checks the factor of safety for a given rope application for the upper levels and lets that govern the size of the rope he is unconsciously following the new method proposed here.

The margin established by the U. S. Bureau of Mines is the static or dead load factor of safety. A discussion of the old safety factor standards published in 1923³ states that the acceleration stresses should be kept out of the factor of safety calculations. On the contrary, acceleration stresses should be included. Figs. 4, 5, 7, and 9 show the effect of acceleration on factor of safety values.

An operating factor of safety is recommended which will include the stress added by acceleration forces. The additional stress due to an acceleration rate of 3.216 ft per sec per sec, or 0.10 g, will increase the overall stress on a rope by 10 pct and lower the static factor of safety by nearly 9.1 pct. If the factor of safety for 1¼-in. plow steel rope is 5.55 at 2500 ft, the total connected load at the end of the cable would be reduced by 2113 lb with the inclusion of acceleration stress from an acceleration of 3.216 ft per sec per sec. Some acceleration and deceleration rates are higher than the value mentioned, so that this additional force can make an appreciable difference in the actual factor of safety of the hoisting rope. This is shown in Fig. 4.

The plotting of a safety factor characteristic curve for a given hoisting rope is as follows. The operating stress is first calculated for different depths, at points close enough together to give a smooth and consistent curve. These points are then plotted on a graph on which curves *A*, *B*, *C*, and *D* are already plotted and a curve is drawn through the points. It can then be seen at a glance how the particular rope application compares with the standard for all sections of the shaft.

Fig. 4 illustrates what is probably an extreme condition, but one allowed by the present factor of safety requirements. The safety factor characteristic curve for a 1¼-in. improved plow steel rope is plotted as curve *F*. The rope is loaded so that the factor of safety at 4000 ft is 4, the minimum allowed by the table for static loading. A comparison of curve *F* with curve *A* shows that the application could be allowed for any distance between 3000 and 4000 ft; a comparison of curve *F* with curve *C* reveals that it could not be used for anything above 4000 ft; and a comparison of curve *F* with curve *D* indicates that above the 1500 ft point the factor of safety requirements for the new cable would not equal even the point of discard standard. Inclusion of any acceleration stress lowers the factor of safety so that the rope should not be considered in any case.

Table II. Comparison of Old and New Values for the Safety Factor for Various Depths

Length of Rope, Ft	Minimum Factor of Safety for New Rope		Minimum Factor of Safety When Rope Must Be Discarded	
	Old	New	Old	New
0	8.57	7.75	6.92	6.19
500	7.5	7.18	6.21	5.74
1000	6.67	6.69	5.63	5.35
1500	6.0	6.26	5.14	5.01
2000	5.45	5.88	4.74	4.71
2500	5.0	5.55	4.39	4.44
3000	4.62	5.25	4.09	4.21
3500	4.29	4.98	3.83	3.99
4000	4.00	4.74	3.6	3.8
4500	3.75	4.52	3.4	3.63
5000	3.49	4.32	3.22	3.47

It should be noted that with this low factor of safety or high unit stress in the rope the safety factor characteristic curve for the rope is much flatter than the minimum required curve, *C*. If the unit stress in the rope is lessened or the factor of safety increased, the characteristic curve becomes steeper. The use of better grades of steel in rope results in flatter safety characteristic curves.

In Fig. 5 the loading for the 1¼-in. improved plow steel rope has been lessened, or the factor of safety increased, so that under static loading and at 4000 ft the factor of safety is 5.6. Curves *G* and *H* are calculated with the same loading but include ac-

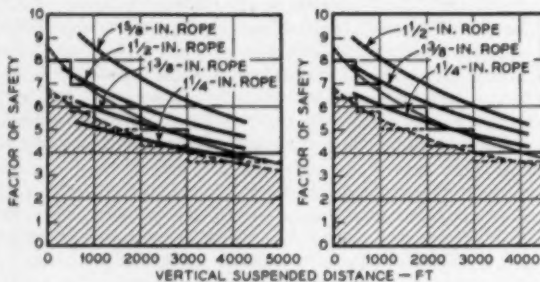


Fig. 6a (left) and Fig. 6b (right)—Studies of rope requirements for a new installation. Note that the calculated factors of safety are operating, not static. All ropes are made of improved plow steel.

At left, capacity: 1000 tons in 12 hr hoisting.

At right, capacity: 1000 tons in 12 hr hoisting.

Rope speed: 1200 fpm.
Weight of cage: 3800 lb.
Weight of skip: 6500 lb.
Weight of ore: 10,200 lb.
Maximum depth: 4000 ft.

Rope speed: 1500 fpm.
Weight of cage: 3000 lb.
Weight of skip: 4800 lb.
Weight of ore: 8350 lb.
Maximum depth: 4000 ft.

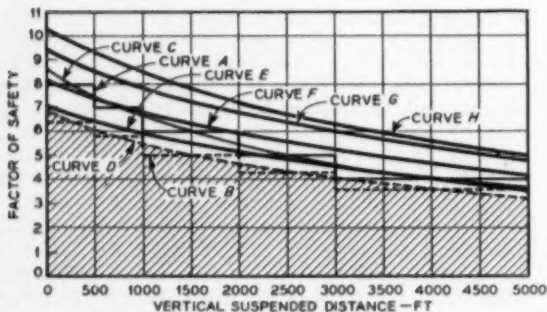


Fig. 7—Comparison of various grades of steel ropes to particular installation. Load is selected to load the 1 1/4-in. mild plow steel rope to a factor of safety of 4 at 4000 ft, equal to 13,206 lb. The mild steel, plow steel, and the improved plow steel ropes to be made of 6x19 or 6x21 construction and the flattened strand rope to be made of improved plow steel wire.

Weight of cage, skip, and ore: 13,206 lb for all ropes. Acceleration rate to be 1.608 ft per sec per sec.

Curve E—Mild plow steel rope, 1 1/4 in.; weight per ft, 2.50 lb; 97,000 lb breaking strength.
Curve F—Plow steel rope, 1 1/4 in.; weight per ft, 2.50 lb; 112,400 lb breaking strength.
Curve G—Improved plow steel rope, 1 1/4 in.; weight per ft, 2.50 lb; 129,300 lb breaking strength.
Curve H—Flattened strand rope, 1 1/4 in.; weight per ft, 2.81 lb; 142,000 lb breaking strength.

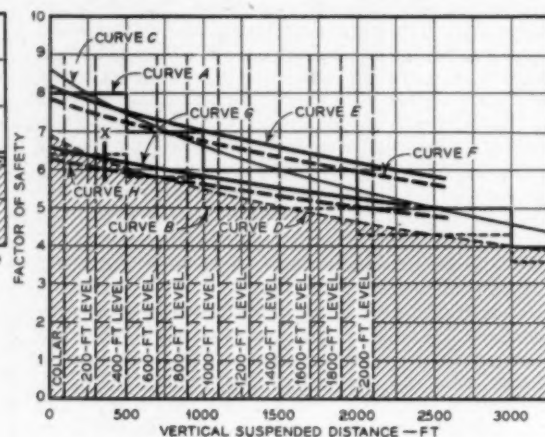


Fig. 8—Characteristic curves of rope used on 400-hp electric hoist. Shaded area is that portion below curve D when rope must be discarded.

Conditions under which hoist was designed.

Weight of skip and cage: 8740 lb.
Weight of ore: 7120 lb.
Size of rope: 1 1/2 in.

Speed of hoist: 1200 fpm.
Maximum depth: 2000 ft.

Conditions under which hoist was used.

Weight of skip and cage: 8000 lb.
Weight of ore: 5000 lb.
Size of rope: 1 1/2 in.

Speed of hoist: 1200 fpm.
Maximum depth: 2000 ft.

Curve E—Characteristic curve for rope, static, designed conditions.
Curve F—Characteristic curve for rope, operating, designed conditions.
Curve G—Characteristic curve for rope, static, actual working conditions.
Curve H—Characteristic curve for rope, operating, actual working conditions.

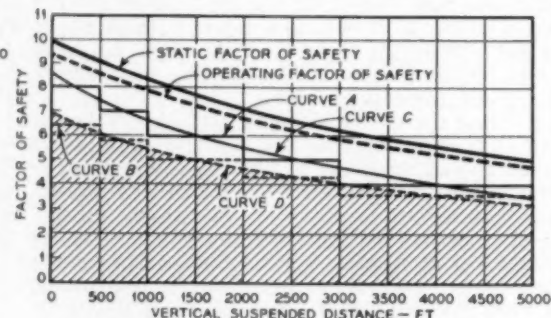


Fig. 9—Characteristic curve of rope used on 2150-hp double-drum electric hoist. Shaded area is that portion below curve D when rope must be discarded.

Weight of skip and cage: 14,500 lb.
Weight of ore: 14,000 lb.
Size of rope: 1 1/2 in. improved plow steel.

Weight of rope: 5.63 lb per ft.
Breaking strength of rope: 141 tons or 282,000 lb.
Acceleration rate: 1.875 ft per sec per sec.

celeration, as was done in Fig. 4. These curves show, even with the lighter loading, the effect of acceleration stress on the factor of safety of a hoisting rope. With lessening of load on any given cable, safety factor characteristic becomes steeper.

When specifications for a new hoist are being considered, usually the only definite information to work from is the total tonnage desired in so many hours hoisting from a certain maximum depth. Fig. 6a presents two sets of curves worked out for a particular installation, each set indicating how various

rope sizes fit into the application with a given rope speed. Fig. 6b presents a set of curves for the same installation but for a different hoist speed.

Even a casual study of these curves leaves no question as to the size of rope that would be necessary for each speed. If the factor of safety for the rope selected is high, the curves will indicate the additional pay load that can be added within the safety limits for the full length of the shaft.

Fig. 7 shows how ropes made with different grades of steel fit into the picture. In this case both the ac-

celeration rate, 1,608 ft per sec per sec, and the combined weight of cage, skip, and ore, 13,206 lb, are the same for each rope. The curves show that ropes of higher steel strength increase the safety factor. The flattened strand rope is of the same grade of steel as the improved plow steel rope but of different stranding construction. It is interesting to note that at the 4000 ft point there is a 15 pct increase in safety factor when the plow steel rope is used instead of the mild plow steel and also a 15 pct increase in safety factor when improved plow steel is used instead of plow steel. Although the flattened strand is approximately 10 pct stronger than the improved plow steel, it weighs 12.4 pct more per ft and therefore adds only 4.53 to the safety factor value.

In the example given above the flattened strand rope does not show up advantage as it does if the allowable connected load using a constant safety factor of 5.55 at 2500 ft is compared. When this comparison is made, the allowable connected load of improved plow steel is 22.5 pct over that of plow steel and the allowable connected load for flattened strand rope 9.1 pct over that of improved plow steel.

Setting aside other advantages there might be in using flattened strand rope rather than improved plow steel for a new installation, its superior strength is not sufficient to justify the additional cost. However, when the rope factor of safety is slightly low in an old installation, or when it is desirable to increase the payload of the hoist and still maintain the former margin of safety, flattened strand rope can be used to advantage.

Safety factor characteristic curves for two typical hoisting applications are shown in Figs. 8 and 9. Fig. 8 shows the curve for a 400-hp double-drum electric hoist originally designed to take 1 1/4-in. rope while hoisting a total connected load of 13,000 lb from a maximum depth of 2000 ft. At this particular installation there were times when an extremely high-grade galena ore was hoisted, the weight of the ore per cubic foot being considerably higher than the value used in the design of the skip. When this occurred the rope was then operating on the factor of safety curve shown as curve I. After about 5 years of operation the hoist was halted by the emergency stop when the upcoming skip was about 400 ft from the sheave, or point x on the curve, and the rope broke. At this point, with the actual loading, a new rope would not fulfill the conditions even at the point of discard. Immediately after the accident, the rope was changed to 1 1/4-in. improved plow steel and the weight of the skip, cage, and ore reduced, so that the factor of safety at all times was maintained at a higher level.

It is general practice to check the safety factor for maximum depth only, no thought being given to probable increase in the density of ore hoisted. The above illustration, which shows the fallacy of such practice, indicates that plotting the safety factor characteristic curve is needed as a rapid means of determining the fitness of a given rope for a particular application.

Fig. 9 shows the safety factor characteristic curve for rope installed on a large electric hoist for a mining company in the West. This curve was calculated from information published in one of the mining journals. The double-drum electric hoist is driven by a 2150-hp dc motor. The load consists of the weight of skip and cage, 14,500 lb, and the weight of ore, 14,000 lb. The rope used is 1 3/4-in. improved plow steel operating at 2300 ft per min from a maxi-

mum depth of 5200 ft. According to the characteristic curve for the operating safety factor, which is 5.22 at 4000 ft, the allowable wear area of the rope is near 33 1/3 pct for the full length of the shaft.

Comparison of a number of characteristic curves reveals that the safety factor characteristic curve for a given grade of rope at the same rate of acceleration, starting with the same factor of safety, for example, 5.55 at 2500 ft, will hold very close to the same line for all sizes of rope for that grade. The variation is only 0.22 for zero length of rope and 0.06 for 5000 ft of rope between the sizes of 3/4 in. and 2 1/4 in. for improved plow steel. It is therefore possible to draw safety factor characteristic curves for any particular grade of rope with different amounts of loading and with various rates of acceleration; the same family of curves would be applicable for all sizes of rope of the same grade, such as improved plow steel.

In conclusion, these points should be considered:

1—In this paper values have not been questioned for the minimum factor of safety for the point of discard. It is suggested, however, that employing a smooth curve instead of the step curve will lessen confusion at the vertical jogs in the line which might raise the question as to what value to use. It is also recommended that values for the various depths be changed slightly so that they fall along the inherent safety factor characteristic curve for an improved plow steel rope with a breaking point of 80 pct of that proposed for the new rope. Although the old values set up some 30 years ago appear to have stood the test of time, to match the progress in metallurgy and manufacture of steel hoisting ropes a re-evaluation should be made by a committee.

2—It is suggested that the minimum factor of safety for new ropes be set up as a smooth curve, the slope of which would closely approximate that of improved plow steel rope. It would then be possible to assign allowable load values to each size of rope and grade and rate of acceleration. If these load values were not exceeded the factor of safety for the rope would automatically take care of itself without further calculation.

3—The factor of safety should include the stress of acceleration, that is, the factor of safety should be an operating value.

4—Consideration should be given the rates of deceleration during emergency stops, which can be made at any portion of the shaft. It is believed that on some ac-powered hoists rate of deceleration may go as high as 1.0 g or more. In such cases, stress on the rope on the down-going skip side, although the skip is empty, would be considerably greater than when a loaded skip is accelerated. A closer definition of maximum stress on a rope is also valuable in determination of maximum stress in members of skips and cages.

5—To prolong the life of a rope, the safety factor characteristic curve can be used to schedule rope cutbacks and end reversals. This phase of the application will best be considered at a later date.

References

- ¹U. S. Bureau of Mines: *Safe Practices in Mine Hoists*. Circular 61.
- ²R. M. Raymond: *Safety Practice for Hoisting Ropes*. Discussion, *Trans. AIME* (1923) 68, pp. 182-188.

Phosphate Rock as an Economic Source of Fluorine

by W. L. Hill and K. D. Jacob

Fluorine recovery in the United States has been restricted chiefly to manufacture of ordinary superphosphate and wet-process phosphoric acid. However, there is an expanding use of fluorine by industry in the form of hydrofluoric acid. Improved methods for recovering fluorine from phosphate rock would yield an adequate supply of fluosilicates and a substantial contribution to the hydrofluoric acid requirement.

THE bulk of natural phosphates is comprised of calcium phosphates, which are usually apatites;¹ calcium aluminum phosphates such as pseudowavellite;² and aluminum phosphates, which occur in extensive deposits, notably on Grand Connetable Island.³ Nearly all deposits of current commercial value are apatite, often with admixed material of other classes. In the trade coarsely crystalline material, mainly fluorapatite of igneous origin, moves as apatite, whereas the fine-grained material of sedimentary origin is marketed as phosphate rock. The latter classification includes the phosphate shales in western North America. Although several genetic varieties of phosphate rock are recognized,⁴ most known reserves are of marine origin. Calcium phosphate is concentrated from Florida land pebble and Florida hard rock deposits and from Tennessee brown rock deposits.

Phosphate Rock as a Fluorine Carrier: More than two decades ago Reynolds and Jacob surveyed the fluorine content of commercial phosphate rock from various parts of the world.^{5,6} Later these samples were re-analyzed by a new and more reliable method of determining fluorine.⁷ The revised results with interim additions of new samples, published a few years ago in a brief summary,⁸ are shown in Figs. 1-3. Through the points representing the respective varieties of rock medial straight lines are drawn. In some instances the lines are well defined by the points; in others, where scattering renders the position of the best line uncertain, the greater weight is given points near the end of the covered range. Wherever distinct varieties are not recognized among regional deposits the custom is to identify the sample with the geographical location of the deposit.

Although all rock varieties cannot be classified with certainty, the plotted results exhibit three distinct types of rock in which the F to P_2O_5 ratio diminishes, remains sensibly constant, and increases, respectively, as the grade of rock increases. Existence of two types of Florida land pebble, Fig. 1, is supported by additional results recently supplied by a producer.⁹

Generally speaking, phosphate rock from continental deposits carries considerably more fluorine, and apatite and insular phosphates less, in proportion to the phosphorus content than is required by the formula for fluorapatite. Exceptions to this are apatite from Canada and certain samples of Florida waste-pond phosphate. The manner in which excess

fluorine is held and the nature of the carbonate in carbonate apatite are discussed in recent articles.¹⁰⁻¹² High-grade calcium phosphates with F to P_2O_5 ratios less than 0.05 have been found in Curacao, Christ-mas Island,¹³ Mexico,¹⁴ and elsewhere.

The calcium aluminum phosphates and aluminum phosphates often carry notable amounts of fluorine. The F to P_2O_5 ratio for one sample of pseudowavellite concentrate was 0.05.² Aluminum phosphate from Grand Connetable Island is very low in fluorine, whereas some aluminum phosphate minerals² carry as much fluorine as highly fluorinated phosphate rock.

Fluorine in Domestic Phosphate: The curves shown in the figures permit interpolation of the F to P_2O_5 ratio corresponding to the midpoint of selected ranges in grade of any one of the several varieties of phosphate. Multiplication of the interpolated ratio by the mid-range grade (P_2O_5) yields a figure for the percentage of fluorine in this grade. Then, with the use of the mid-range grade, the amount of fluorine held in phosphate reserves can be estimated, see Table I. Accordingly, on Jan. 1, 1950, the fluorine complement of known domestic reserves exceeded 420,000,000 long tons of the element. A previous figure,¹⁴ deduced in 1940 by a simpler procedure

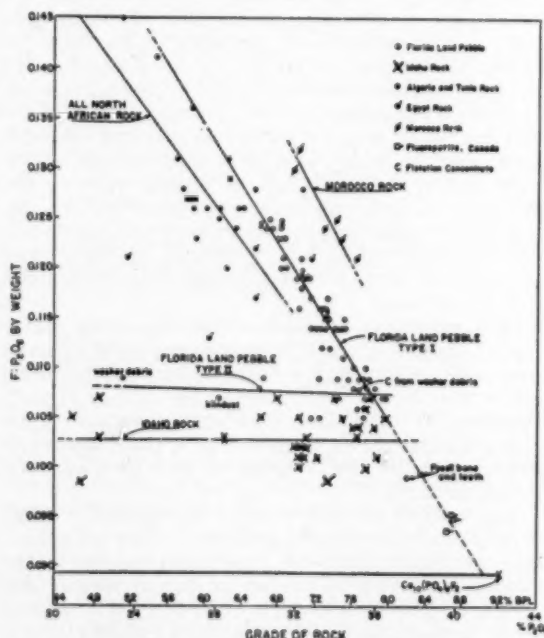


Fig. 1—The fluorine-phosphorus ratio in phosphate rock: Florida land pebble, rock from Idaho and North Africa, and apatite from Canada.

W. L. HILL and K. D. JACOB are Principal Chemist and Head, respectively, Division of Fertilizer and Agricultural Lime, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture, Beltsville, Md.

Discussion on this paper, TP 3908H, may be sent (2 copies) to AIME before Dec. 31, 1954. Manuscript, Nov. 12, 1953. Nova Scotia Meeting AIME, September 1953.

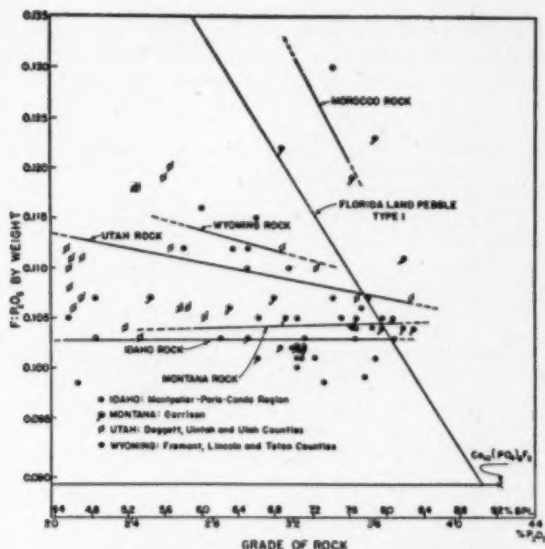


Fig. 2—The fluorine-phosphate ratio in phosphate rock from western United States.

for a reserve some 19 million tons below the 1950 estimate, is 415,192,000 long tons.

From published figures for domestic production of phosphate rock, and the tonnage of P_2O_5 , it is possible to calculate the average grade and determine the F to P_2O_5 ratio by interpolation from the graphed results, see Table II. From this calculation the 1950 U. S. marketed production of phosphate rock carried 421,000 tons of fluorine.

Fluorine Carried in Rock Going to Manufacturing Processes: Marketed production of rock in 1950 was divided¹² among uses as follows: exports, 17 pct; direct application to soil and fertilizer filler, 9 pct; stock and poultry feed, 1 pct; chemical processing, 73 pct. By far the larger share of rock going to

Table I. Estimated Quantity of Fluorine in Known Domestic Phosphate Reserves as of Jan. 1, 1950

Variety or Location of Deposit	Phosphate Reserves,* Long Tons	Fluorine** Content, Pct	Fluorine in Reserves, Long Tons
Florida			
Land (and river) pebble	3,499,892,000	3.69†	129,146,015
Hard (and soft) rock	>1,539,778,000	2.90	>46,039,362
Tennessee			
Brown (and white) rock	120,257,000	3.01	3,619,736
Blue rock	83,233,000	2.98	2,455,373
Western States			
Idaho and Montana	6,123,307,000	2.92	178,806,565
Utah and Wyoming	1,935,065,000	3.10	59,987,015
Other			
South Carolina land rock	8,798,000	3.12	274,498
Virginia apatite	2,000,000	2.85	57,000
Total	>13,312,330,000		>420,379,564‡

* Figures given by Jacob¹³ for material containing 40 or more pct P₂O₅.

** Medial percentages are given for varietal combinations.

† Result for main series (Type I).

‡ Rounded figure in short tons is 471,000,000.

chemical processing was used in production of superphosphate, phosphoric acid, and phosphorus. It should be noted that electrothermal phosphoric acid,¹⁴ see Table III, is now produced solely from phosphorus and that a very large part of the phosphorus production is thus consumed. Most, if not all, the production of Florida hard rock was used in phosphorus manufacture; the entire marketed production, see Table II, is assumed to have been so used. Indicated

tonnages for other varieties listed under Phosphorus in Table III were deduced indirectly. The difference between the marketed production going to superphosphates and to phosphates, phosphoric acid, phosphorus, and ferrophosphorus¹⁵ and that used in the manufacture of ordinary superphosphates, wet-process phosphoric acid, and triple superphosphate, Table III, is presumably the rock used in furnace processes of manufacture, that is, phosphorus (and electrothermal phosphoric acid) and other furnace processes. Tonnages thus obtained can be reconciled with the elemental phosphorus production, 153,233 short tons, on the basis of an apparent overall recovery of 80 pct of the rock phosphorus going to phosphorus manufacture and leave a balance of 118,350 tons of rock (P_2O_5 content indefinite) as the apparent consumption in the other furnace processes. In the computation the latter quantity of rock was divided equally between Florida land pebble and Tennessee rock, see Table III, and deducted from the respective total quantities indicated for furnace processes.

The recovery factor was derived from the 87.2 pct of the phosphorus actually charged into the furnace, found by tests¹⁷ in which the slag carried 1.0 pct P_2O_5 , which would reduce the stated factor to 83.6 pct. Allowance for a 1 pct P_2O_5 loss in preparation of the furnace feed and for 3 pct moisture in the rock reduces this factor to the figure employed.

Phosphate rock going to these major chemical processes in 1950 carried about 295,000 short tons of fluorine. Summation of percentages for Florida land pebble shows that 82 pct of the fluorine was carried in this variety of rock. Interestingly enough, the quantity of fluorine fed into these processes nearly equals domestic shipments of fluorspar of all grades, 301,510 short tons,¹⁸ from the mines in 1950.

Fluorine Evolution: Results for the percentage evolution of fluorine in the several processes involved in domestic manufacture of superphosphate, phosphoric acid, and phosphorus are assembled in

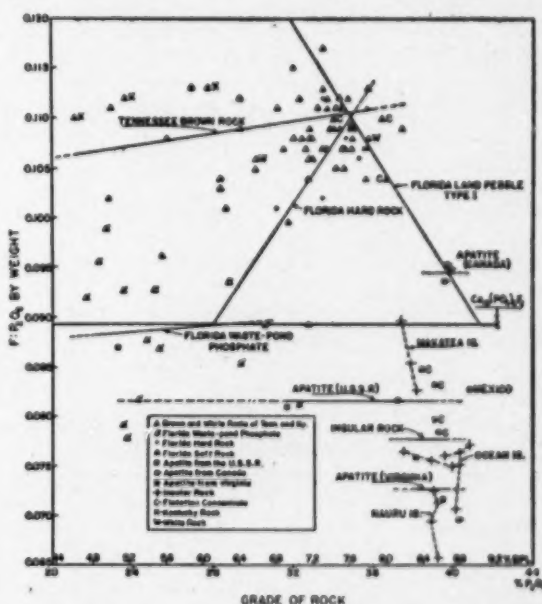


Fig. 3—The fluorine-phosphate ratio in phosphate rock: Florida hard-rock and waste-pond phosphates, Tennessee brown rock, various insular phosphates, and apatite from sundry deposits.

Table IV. Unfortunately, figures covering major rock varieties in all manufactures are not available, being notably deficient for phosphorus. Information of a qualitative nature from sundry sources indicates that fluorine evolution from Tennessee brown rock in smelter operations is not greatly different from that occurring from other varieties under the same conditions. Suitable combinations of the percentage

Table II. Fluorine in Marketed Production of Domestic Phosphate Rock in 1950

Variety and Source of Rock	Sold or Used by Producers*		Average** F:O ₃ Pct	F:O ₃ :F Pct	F, Long Tons
	Rock, Long Tons	P ₂ O ₅ , Long Tons			
Florida					
Land pebble	7,933,009	2,673,862	33.7	0.114	304,623
Hard rock	71,319	25,133	35.4	0.111	2,790
Soft phosphate	81,542	16,994	20.8	0.0680	1,156
Western states					
Idaho, Utah and Wyoming	573,044	163,272	28.5	0.106	17,633
Montana	210,165	66,641	31.7	0.104	6,931
Tennessee					
Brown rock	1,384,473	390,190	28.2	0.109	42,531
Total	10,283,552	3,336,112			375,664†

* Figures reported by Johnson and Jensen.¹²

** Calculated from figures in preceding columns.

† Obtained from Figs. 1, 2, and 3 for average grades using medial values of variational combinations.

‡ Rounded figure in short tons is 421,000.

evolutions permit computation of the quantities evolved, as illustrated in Table V. Among tonnage data the figure for evolution in triple superphosphate production with wet-process acid is perhaps the least secure, because of the diversity in triple superphosphate manufacture. Plant to plant variations which influence the evolution markedly include acidulation with production acid, with moderately concentrated acid, and with concentrated acid. In the first two cases the product is kiln-dried, a process now sometimes merged with a granulation step, whereas with concentrated acid it is pile-cured. On the basis of published results²⁰ and information from private sources, it appears that about 42 pct of the production of wet-process acid was concentrated

from an average production grade of 24.1 pct P₂O₅ to grades averaging 45.9 pct P₂O₅. The total quantity of phosphoric acid going to triple superphosphate production was divided as follows: wet-process acid 79.5 pct and electrothermal acid 20.5 pct.²⁰ The fluorine carried into the manufacture by the rock, 10,028 tons, is divided in this proportion between treatments by the two varieties of acid.

Other types of phosphate processing in which fluorine is given off include treatment of rock with gaseous P₂O₅ to produce calcium metaphosphate;²¹ thermal defluorination of phosphate rock^{22, 23} or a blend of rock and phosphoric acid;²⁴ calcination of rock with alkali salts to produce a Rhenania type of phosphate,^{25, 26} or with magnesium silicates to produce calcium-magnesium phosphate silicate glass;^{27, 28} defluorination of ordinary superphosphates;²⁹ granulation of ordinary superphosphate; and rock-drying operations. As a rule negligible evolution occurs in the latter treatment.

Defluorinated superphosphate, a secondary product prepared by heating superphosphate under conditions that volatilize 90 to 95 pct of the fluorine, is not included in the figures for defluorinated rock. Volatilization in the manufacture of calcium-magnesium phosphate-silicate glass ranges from 10 to 20 pct;²⁷ domestic production has ceased. Fluorine evolution in the manufacture of Rhenania-type phosphate is influenced markedly by conditions of processing. As the process is operated in Germany²⁵ for fertilizer manufacture with the use of apatite, for example, and a furnace temperature of 1100° to 1200°C, volatilization amounts to about 8 pct of the fluorine carried in the apatite.

In calcium metaphosphate production about 70 pct of the fluorine in the rock treated is evolved and the product contains about 63 pct P₂O₅ and 0.5 pct F.³⁰ Production in 1950 amounted to 15,500 tons of P₂O₅. According to these data the evolution must have been about 300 tons. Furthermore, published results²⁰ indicate that, tonnage-wise, the ratio of rock used to product obtained is near 0.535; with data already given this means that 13,000 tons of rock were treated. Deduction of this quantity of rock from the

Table III. Rock Used in Superphosphate, Phosphoric Acid, and Phosphorus Production in the United States in the Calendar Year 1950

Variety of Rock	Quantity, Short Tons	Grade Range, BPL, Pct	Fluorine Content,* Pct	Fluorine	
				Quantity, Short Tons	Share of Total, Pct
Ordinary Superphosphate**					
Florida land pebble	5,072,663	70 to 77	3.74	189,718	64.3
Tennessee brown rock	68,399	68 to 75	3.60	2,462	0.8
Rock from western U. S.	110,350	68 to 80	3.59	3,962	1.3
Total	5,251,412	68 to 80		196,142	66.4
Wet-Process Phosphoric Acid**					
Florida land pebble	885,424†	72 to 79	3.80	33,646	11.4
Tennessee brown, Idaho and Wyoming rocks	177,506	66 to 70	3.36	5,904	2.0
Total	1,062,930	66 to 79		39,610	13.4
Phosphorus (and Electrothermal Phosphoric Acid)					
Florida land pebble	274,669	60 to 68	3.75	10,300	3.5
Florida hard rock	79,877	‡	3.93	3,139	1.1
Rocks from Tennessee and western U.S.	1,362,295	‡	2.62	35,692	12.1
Total	1,716,841			49,131	16.6
Triple Superphosphate (Phosphoric Acid Treatment of Rock)**					
Florida land pebble	225,993	72 to 76	3.73	8,430	2.9
Tennessee brown, Idaho and Wyoming rocks	48,129	64 to 70	3.32	1,596	0.6
Total	274,122	64 to 76		10,028	3.5
All varieties and processes	8,423,655	ca. 52 to 80		294,911	100.0

* Obtained from F to P₂O₅ ratios shown by graphed data for the grade range given in preceding column.

** Quantities and grades of rock going to this manufacture are given by Adams et al.¹⁹

† Inclusive of 11,539 tons of 68 pct BPL rock, which has been neglected in the grade computations, being a small fraction of the variational total going to this use.

‡ Only the average grade is known (Table II).

§ The average grade of rock going to phosphorus manufacture in the western phosphate field is said to be 24 pct at the present time.

Table IV. Fluorine Volatilization in Domestic Manufacture of Superphosphate, Phosphoric Acid, and Phosphorus

Rock Variety, Product, or Treatment	Fraction of Rock Fluorine Evolved			
	Determinations, Number	Range, Pct	Average, Pct	Mid-range, Pct
Ordinary Superphosphate*				
Acidulation step:				
Florida land pebble	19	16.5 to 37.8**	26.4	27.1
Tennessee brown rock	11	28.1 to 42.1	34.1	35.1
Idaho and Montana rock	3	33.5 to 38.3	35.7	35.9
All four varieties (30 factories)	33	16.5 to 42.1	29.9	29.3
Granulation step:				
Florida land pebble (experimental runs)	3	0.6 to 2.2	1.7	1.4
Wet-Process Phosphoric Acid*				
Production step (acid, 20 to 30 pct P_2O_5):				≥1.0
Florida land pebble (sodium phosphate industry)				
All four varieties (fertilizer industry)	4	5.2 to 23.7	13.0	14.5
All four varieties (both industries)		<1.0 to 23.7		12.0
Concentration step (acid, 39 to 50 pct P_2O_5):				
All four varieties (concentration step only)	4	10.0 to 38.7	27.4	24.4
Phosphorus (and Electrothermal Phosphoric Acid)*				
Preliminary treatment of rock:				
Tennessee brown rock, nodulization		12.8 to 40		26.4
Tennessee brown rock, sintering		10 to 20		15.0
Tennessee brown rock, briquetting and calcination		10 to 20		15.0
Tennessee brown rock, all treatments		10 to 40		25.0
Smelting process:				
Pre-treated rock		0.3 to 4†		2.2‡
Raw lump rock		20 to 30		25.0
Triple Superphosphate (Phosphoric Acid Treatment of Rock)*				
Acidulation step:				
Wet-process acid, 41.7 to 44.7 pct P_2O_5	2	7.5 to 13.4‡§		10.5‡
Electrothermal acid, 54 to 56 pct P_2O_5			4	
Acidulation and kiln-drying steps:				
Wet-process acid, 39.0 to 41.7 pct P_2O_5	2	13.6 to 50.2‡§		31.9‡

* Results given by Jacob et al.¹⁰ Supplemental data for wet process phosphoric acid were supplied privately by Blockson Chemical Co. Supplemental data for phosphorus (and electrothermal phosphoric acid) were supplied privately by Monsanto Chemical Co., Tennessee Valley Authority, and Victor Chemical Works.

** Result for Oberphos and one obviously unreliable result given in the reference article were disregarded in determination of the range.

† Divided, perhaps about equally,¹⁰ between dust and gaseous fluorine compounds; result calculated on supposition that 90 pct of fluorine in smelter furnace feed remains in the slag.^{17,18}

‡ Results for Idaho rock (acid, 44.7 pct P_2O_5) and Tennessee brown rock (acid, 41.7 pct P_2O_5), respectively.

§ Percentage of fluorine carried into process by both rock and acid.

|| Results for Montana rock (acid, 39.0 pct P_2O_5) and Tennessee brown rock, respectively.

118,350 tons assigned to thermal processes other than phosphorus (and electrothermal phosphoric acid) manufacture yields the figure 105,350 tons, which may be regarded as the apparent rock consumption in production of defluorinated rock. With the usual volatilization of 90 to 98 pct attained in defluorination processes this quantity of rock would yield 3000 to 4000 tons of evolved fluorine.

Division of Fluorine Among Products: In ordinary superphosphate manufacture the fluorine divides between the product and surrounding atmosphere. Evolution is restricted almost entirely to mixing and denning operations. Only negligible amounts escape from the curing pile. On the other hand, in the manufacture of phosphoric acid and triple superphosphate the fluorine, dividing at three or more process stages, is distributed among several products. A possible distribution among the products obtained in the manufacture of wet-process phosphoric acid, triple superphosphate, and sodium phosphates is illustrated in Fig. 4. It must be realized that although individual results all lie within ranges found in industrial practice, the chart does not depict any actual integrated sequence of steps. The division of fluorine shown for the production-acid step was deduced from results from fertilizer operations. By a suitable choice of conditions the quantity going into the filter cake, as well as that evolved, can be made very small. Apparently such practice is followed by some manufacturers of sodium phosphate, with the result that nearly all the fluorine goes into the production acid and is thereafter collected by precipitation from solution.

A probable division of fluorine among products obtained in manufacture of electrothermal phosphoric acid is illustrated in Fig. 5. The fluorine con-

tent of condensed phosphorus runs 10 ppm or less when the condenser is operating properly. The fluorine is held in occluded condenser water.

Disposal of Evolved Fluorine: Nearly 25 years ago it was observed⁹ that whereas superphosphate manufacturers usually absorbed evolved fluorine in water as a disposal measure, a few big producers recovered a large part in the form of marketable fluosilicates, whereas small producers merely ran

Table V. Estimated Fluorine Evolution in Domestic Production of Superphosphate, Phosphoric Acid, and Phosphorus in Calendar Year 1950

Manufacture	Fluorine Entering Process, Pct	Fluorine Evolved		
		Fraction** of Total, Pct	Quantity, Short Tons	Share in Total Evolution, Pct
Ordinary superphosphate (acidulation step)	196,142	29	56,881	69.5
Wet-process phosphoric acid:				
Production step	39,610	12	4,753	5.8
Concentration step	16,636	24	3,993	4.9
Phosphorus (and electrothermal phosphoric acid)	49,131	26†	12,774	15.6
Triple superphosphate:				
Wet-process acid	16,000‡	21‡	3,360	4.1
Electrothermal acid	2,056	4	82	0.1
Total	294,911		81,843	100.0

* Unless it is otherwise indicated in a footnote, the figures are the section totals given in Table III.

** Unless it is otherwise indicated in a footnote, figures are the mid-range results (rounded) shown in Table IV.

† Rounded average of overall figures for evolution with and without pre-treatment (Table IV, Phosphorus and Electrothermal Phosphoric Acid).

‡ Figure includes 7972 tons carried in the rock and an estimated figure for that in the acid.

§ Rounded average of figures for acidulation step and acidulation step with kiln drying (Table IV, Triple Superphosphate).

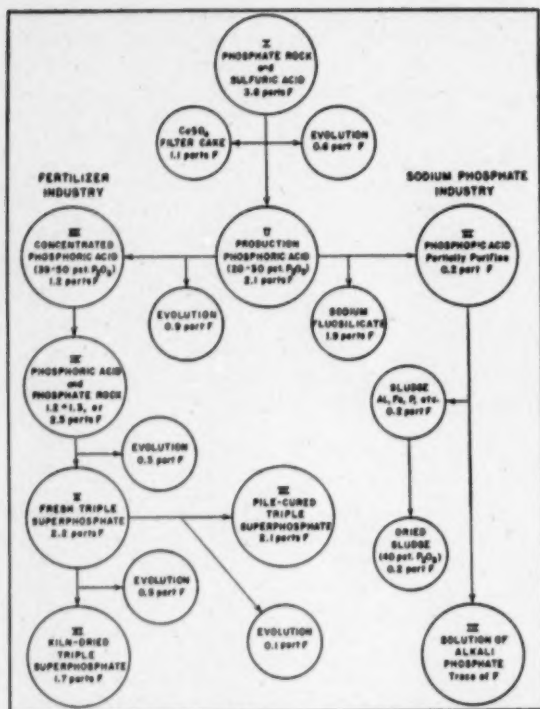


Fig. 4—Illustration of likely division of fluorine in manufacture of wet-process phosphoric acid, triple superphosphate, and sodium phosphate. (Based on data in Table IV, results given by Jacob et al.,¹⁰ and unpublished results).

the absorbed fluorine compounds to waste. At present the bulk of the fluorine evolved in manufacture of phosphoric acid, superphosphate, and other phosphorus-bearing products is removed from the exit gases before they are discharged to the atmosphere. The fluorine is usually either scrubbed out with water or absorbed in a bed of suitable solid materials. Fluorine-bearing solution from the scrubber is often neutralized with hydrated lime before it is run to waste. In certain thermal processes fluorine in the stack gas is rendered innocuous by introduction of lime dust at the base of the stack.

Recovery of Fluorine in Marketable Form: The ideal solution to disposing of evolved fluorine would be to recover it in the form of useful compounds. Unfortunately, at the present time the cost of recovery would often exceed the market value of the product. The quantity of fluorine recovered in phosphate processing is indicated to a fair degree of reliability by the production of fluosilicic acid and the fluosilicates of potassium, ammonium, magnesium, zinc and, principally, sodium. Total output of these materials in 1950 was equivalent to 13,970 short tons of fluorine. This is slightly under 17 pct of the total indicated evolution, see Table V, or about 20 pct of the evolution in manufacture of superphosphate and wet-process phosphoric acid. However, this figure representing total recovery includes non-evolved fluorine reclaimed in the sodium phosphate industry. Actual recovery of volatilized fluorine was less than one-sixth of the indicated total evolution.

The low score on recovery of evolved fluorine can be attributed to unfavorable distribution of evolution and to lack of incentive for recovery. Comparison of results in Tables V and VI reveals points in the process where recovery is most promising. Sizable rock tonnage and high percentage of volatil-

ization present a very favorable combination, and ordinary superphosphate stands high in this regard. Production, however, is widely scattered, see Table VI. The 1951 production came from 204 plants in 32

Table VI. Ordinary Superphosphate Production in Relation to Size of Plants for the Calendar Year 1951*

Annual Capacity, Thousand Short Tons	Number of Plants**	Average Plant Capacity Short Tons	Average Plant Production, Short Tons	Group Share in Total, Pct
<25	7	17,600	9,800	0.7
25 to 50	35	40,000	20,100	7.2
50 to 75	60	61,900	34,300	20.9
75 to 100	54	85,900	44,600	24.5
100 to 200	42	123,300	74,200	31.7
>200	6	261,800	245,900	15.0

* The figures, representing production in Continental United States in terms of superphosphate containing 18 pct of available P₂O₅, are adaptations of data given by Adams et al.¹⁰

** This summary covers 204 plants scattered over 32 states; two of the plants discontinued operation during the year.

states. Furthermore, 53 pct came from 156 plants in which average productions were less than 50,000 tons and required treatment of less than 25,000 tons of rock. Since the average fluorine content of all rock used for manufacture of superphosphate is 3.73 pct, the fluorine complement of this quantity of rock is only 930 tons, of which 29 pct, see Table V, or 270 tons is estimated evolution. In the light of these figures the paucity of recovery units in proportion to the number of plants is understandable. According to a recent survey¹¹ only 19 recovery units were co-existent with ordinary superphosphate plants in 1951. Five of these were not being operated, probably because a weak fluosilicate market did not offer sufficient incentive.

Similar conditions prevail in the manufacture of wet-process phosphoric acid and triple superphosphate. In 1951 13 plants producing wet-process acid shared in the rock equivalent of nearly 40,000 tons of fluorine, see Table III, with an average of 3000 tons each. Only two plants had recovery facilities. Of the nine plants producing triple superphosphate only one recovered fluorine.

Fluorine evolved in the phosphorus smelter furnace is caught in the phosphorus condenser water. Small amounts of fluosilicates were recovered from this source in England for a number of years prior to 1914.¹² As far as the authors are aware recovery from this source has not been practiced elsewhere. Recent work on recovery of fluorine evolved in a defluorination plant¹³ points to a promising method that should be generally applicable to furnace stack gases. The process, put into regular operation a short time ago, produces a metallurgical grade of calcium fluoride.

Trends and Outlook

It remains to list and evaluate changes in the fluorine economy that are now under way or may come in the future. Attention is directed to actual and possible changes in patterns of evolution, recovery and markets, and needed technological advances.

Evolution: Undoubtedly fluorine evolution has increased since 1950 because larger tonnages of rock have been going to chemical processes. In comparison with 1950 percentage production increases for the chief primary products in 1951 and 1952 are, respectively: ordinary superphosphate, 2 and 5; wet-process phosphoric acid, 17 and 34; phosphorus (and electrothermal phosphoric acid), 12 in 1951; triple superphosphate, 7 and 26. If the pattern of evolution had not changed during the interim, the

1952 evolution would have been 10 pct above that for 1950. Probably the increase was appreciably less than 10 pct, because steadily increasing quantities of wet-process phosphoric acid are being utilized without concentration in the manufacture of fertilizer-grade ammonium phosphate and feed-grade dicalcium phosphate. Nitric acid treatment of phosphate rock, about ready for commercial development for production of fertilizers, promises little for fluorine evolution in phosphate processing.

In the future, procedures may retain fluorine at unfavorable points in the process for expulsion at more favorable places. Also, business developments may concentrate production in a few large operations. The expanding triple superphosphate industry has exhibited a trend toward production concentration, although preparation of this material in the conventional ordinary superphosphate plant is a step in the other direction.

Recovery: Fluorine recovery in phosphate processing in the United States has been restricted mainly to manufacture of ordinary superphosphate and wet-process phosphoric acid, with some contribution from triple superphosphate. The products are fluosilicic acid and its salts. As indicated earlier in this article, it is now being recovered from furnace stack gas in the form of a metallurgical grade of calcium fluoride. The one recovery unit now in operation undoubtedly will demonstrate the possibilities of recovery from furnace stack gas. It is to be hoped that this will lead to improvement in the quality of calcium fluoride and encourage installations for recovery from this source. The winning of marketable fluorine compounds from phosphate solutions, heretofore practiced mainly in the sodium phosphate industry, is feasible in the manufacture of feed-grade dicalcium phosphate from wet-process acid. Recovery in this manner is anticipated in the new plants for this manufacture. Although fluorine evolution would be affected adversely by increased production of dicalcium phosphate for feed use, since concentration of the phosphoric acid is not necessary, recovery would probably be enhanced as a consequence of the precipitation technique.

Market Pattern: The fluosilicate market was satisfied in 1950 by fluorine recovery in phosphate processing without the utilization of the full recovery capacity. At the same time a part of the fluosilicate was consumed in the manufacture of sodium fluoride. It can be concluded, therefore, that phosphate rock was at that time an economic source of some 14,000 short tons of fluorine, which was supplied mainly by large operations. Recently the advent of water fluoridation has increased the demand for sodium fluosilicate and thus greatly stimulated interest in fluorine recovery. The significance of this new use as a factor in the fluosilicate market can be made obvious with the aid of a few figures. In 1950 13,600 million gallons of water per day were furnished by public water supplies in the United States.²⁰ An unpublished estimate for 1952 is 16,000 million gallons per day. For fluoridation 1 part F per million parts water is the addition generally recommended,²¹ and either the fluoride or fluosilicate of sodium can be used. Accordingly 21,000 short tons of fluorine would have been required to fluoridate the entire public supply in 1950; by 1952 an additional 3000 tons would have been needed. It is estimated²² that 100 million people are served by public supplies, of which 3.5 million reside in areas where adequate fluorine is carried in the water. Thus 96.5

pct of 24,000, or 23,200 tons, would have been the limiting tonnage for this use in 1952. On July 15, 1953, fluoridated water was used by 14.5 million people, about twice the number in the preceding year, whereas other communities representing 15.6 million people are now considering fluoridation. Supposing that the proposed adoptions materialize promptly, the indicated growth of fluoridation is 7, 15, and 30 pct of the public water supply in the years 1952, 1953, and 1954, respectively. Combination of the foregoing results gives the probable tonnages of fluorine required for this use: 1700 in 1952, 3800 in 1953, and 8100 in 1954. Obviously before very long fluoridation will be taking a quantity of fluorine somewhat greater than one-half of the 1950 recovery from phosphate processing. Problems connected with fluoridation in a large plant are discussed in a recent article.²³

There is an expanding use of fluorine by industry in the form of hydrofluoric acid.²⁴⁻²⁶ Industrial consumption increased from 15,500 tons of hydrofluoric acid²⁴ in 1940 to 36,500 tons²⁵ in 1950, and the estimates for 1951 and 1952²⁶ are 44,000 and 47,500 tons. Its principal uses are in aluminum metallurgy, petroleum alkylation, and the manufacture of refrigerants, aerosol propellants, and polyterpene resins. The supply of this chemical comes mainly from fluorspar. In 1950 acid-grade fluorspar shipments²⁷ from domestic mines carried about 46,000 tons of fluorine. The acid-grade material commands a premium price. Prior to 1952 the known accessible reserves were alarmingly inadequate to meet growing demand, although the lower grades were in plentiful supply. The gap has now been closed, and ample supply of acid-grade material is in sight.

Needed Technological Development: At the present time phosphate rock going to chemical processing carries several-fold the quantity of fluorine required by the market demand for fluosilicates and hydrofluoric acid. The indicated actual evolution in 1950 exceeded market demand by about 13 pct. This source could provide not only an adequate supply of fluosilicates but also a substantial contribution to the hydrofluoric acid requirement. Achievement of these

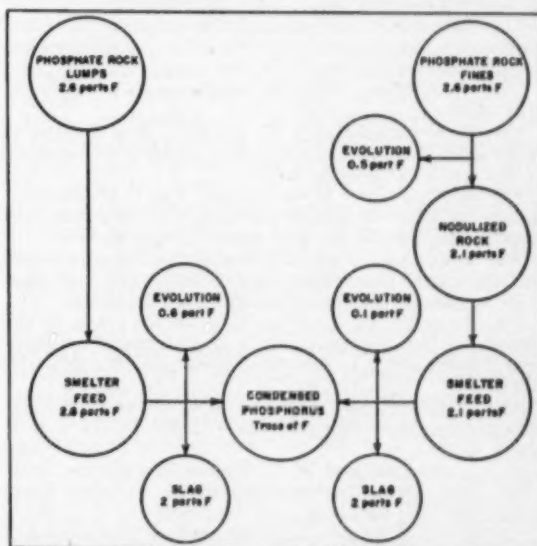


Fig. 5—Illustration of likely divisions of fluorine in manufacture of electrothermal phosphoric acid. (Based mainly on data given in Table IV).

objectives depends on improvements in current recovery practice.

There is need for improved recovery methods to lower equipment cost and/or increase percentage recovery of fluorine evolved in the manufacture of superphosphate and wet-process phosphoric acid. It is said that some recovery units do not reclaim more than 50 pct of the localized evolution. A desirable development for the small plant would be a midget recovery unit.

A method for producing acid-grade calcium fluoride from furnace gases is also needed. This might be an improvement in the TVS process,² which now can produce only the lower grades. A greater economic opportunity would be offered by a method for producing hydrofluoric acid directly from furnace gases, since the acid has a much higher market value. Still another way to obtain hydrofluoric acid from phosphate rock used in fertilizer manufacture lies in the development of a process for economic production from fluosilicates. Until this process becomes a reality, the only hope for supplementing the hydrofluoric acid supply from phosphate rock processing is recovery of fluorine from furnace gas.

References

- ¹ C. Palache, H. Berman, and C. Frondell: *Dana's System of Mineralogy*, Vol. II, 7th ed. New York, 1951.
- ² W. L. Hill, W. H. Armiger, and S. D. Gooch: Some Properties of Pseudowavellite from Florida. *Trans. AIME*, (1950) **187**, p. 699.
- ³ K. D. Jacob, W. L. Hill, H. L. Marshall, and D. S. Reynolds: The Composition and Distribution of Phosphate Rock with Special Reference to the United States. U. S. Dept. Agr. *Tech. Bull.* 364 (1933) 90 pp.
- ⁴ E. Blackwelder: Origin of the Rocky Mountain Phosphate Deposits (Abstract). *Bull.* 26, Geol. Soc. Amer. (1915) p. 100.
- ⁵ K. D. Jacob and D. S. Reynolds: The Fluorine Content of Phosphate Rock. *Journal of the Association of Official Agricultural Chemists* (1929) **11**, p. 237.
- ⁶ D. S. Reynolds and W. L. Hill: Determination of Fluorine with Special Reference to Analysis of Natural Phosphates and Phosphatic Fertilizers. *Industrial and Engineering Chemistry* (1939) **11**, p. 21.
- ⁷ H. H. Willard and O. B. Winter: Volumetric Method for Determination of Fluorine. *Industrial and Engineering Chemistry, Anal. Ed.* (1933) **5**, p. 7.
- ⁸ K. D. Jacob: Phosphorus Supplements for Livestock—Sources, Supplies, and Fluorine-Phosphorus Relations. *Feedstuffs* (1944) **16**, No. 7, 18.
- ⁹ W. T. Whitney: Private communication to W. L. Hill (1953).
- ¹⁰ S. B. Hendricks and W. L. Hill: The Nature of Bone and Phosphate Rock. *Proc., National Academy of Science* (1950) **36**, p. 731.
- ¹¹ Z. S. Altschuler, E. A. Cisney, and I. H. Barlow: X-ray Evidence of Nature of Carbonate-Apatite (Abstract). *Bull.* 63, Geol. Soc. Amer. (1952) p. 1230.
- ¹² D. McConnell: Viséite, a Zeolite with the Analcime Structure and Containing Linked SiO₄, PO₄, and H₂O Groups. *American Mineralogist* (1952) **37**, p. 609.
- ¹³ J. G. Cady, W. L. Hill, E. V. Miller, and R. M. Magness: Occurrence of Beta Tricalcium Phosphate in Northern Mexico. *American Mineralogist* (1952) **37**, p. 180.
- ¹⁴ K. D. Jacob: New and Old Methods of Processing Phosphates. *American Fertilizer* (1940) **93**, No. 8, p. 7; No. 9, p. 7.
- ¹⁵ B. L. Johnson and N. C. Jensen: Phosphate Rock. U. S. Dept. Interior, *Bureau of Mines Minerals Yearbook* (1950) p. 1003.
- ¹⁶ M. M. Striplin, Jr.: Development of Processes and Equipment for Production of Phosphoric Acid. Tennessee Valley Authority *Chemical Engineering Report* No. 2 (1948) 143 pp.
- ¹⁷ R. R. Burt and J. C. Barber: Production of Elemental Phosphorus by the Electric-Furnace Method. Tennessee Valley Authority *Chemical Engineering Report* No. 3 (1952) 312 pp.
- ¹⁸ H. W. Davis: Fluorspar and Cryolite. U. S. Dept. Interior *Bureau of Mines Minerals Yearbook* (1950) p. 521.
- ¹⁹ J. R. Adams, T. H. Tremearne, K. D. Jacob, and L. G. Porter: Survey of the Superphosphate and Wet-Process Phosphoric Acid Industries in the United States in 1950 and 1951. U. S. Dept. Agr., Bur. Plant Industry, Soils, and Agr. Eng. and Office of Materials and Facilities, Processed Report (1952) 44 pp.; New Data on Fertilizer Phosphates (editor's summary). *Chemical Engineering* (1952) **59**, No. 8, p. 142.
- ²⁰ J. C. Brosheer: Development of Processes for Production of Calcium Metaphosphate Fertilizer. Tennessee Valley Authority *Chemical Engineering Report* No. 6 (1953) 102 pp.
- ²¹ J. C. Brosheer and T. P. Hignett: Development of Processes for Production of Fused Tricalcium Phosphate. Tennessee Valley Authority *Chemical Engineering Report* No. 7 (1953) 143 pp.
- ²² W. T. Whitney and C. A. Hollingsworth: Production of Defluorinated Phosphate Rock—Calcining without Fusion in Rotary Kilns. *Industrial and Engineering Chemistry* (1949) **41**, p. 1325.
- ²³ C. A. Butt: Manufacture of Defluorinated Tricalcium Phosphate. U. S. Patent 2,442,969 (June 1948); 2,565,351 (Aug. 1951).
- ²⁴ K. D. Jacob: German Fertilizers and Soil Fertility. Official Military Government for Germany (U. S.), FIAT Final Report 665 (1945) pp. 32-35; U. S. Dept. Commerce, Office of Technical Services PB-18777.
- ²⁵ J. R. Hawes and F. M. Lea: Kali Chemie Rhenania Phosphat Werke Brunsbüttelkoog. U. S. Dept. Commerce, Office of Technical Services PB No. 18913.
- ²⁶ W. L. Hill, F. N. Ward, W. H. Armiger, and K. D. Jacob: Composition and Fertilizer Value of Phosphate Rock—Magnesium Silicate Glasses. *Journal of the Association of Official Agricultural Chemists* (1948) **31**, p. 381.
- ²⁷ R. W. Moulton: Electric Furnace Fertilizer—Ca-Mg-Phosphate. *Chemical Engineering* (1949) **56**, No. 7, p. 102.
- ²⁸ W. H. Waggaman: Phosphoric Acid, Phosphates and Phosphatic Fertilizers. A C S Monograph No. 34, 2nd ed. New York, 1952.
- ²⁹ R. E. Threlfall: The Story of 100 Years of Phosphorus Making 1851-1951. Albright and Wilson, Ltd., Birmingham, England, 1952.
- ³⁰ K. A. MacKichan: Estimated Use of Water in the United States—1950. U. S. Dept. Interior, Geol. Survey *Circ.* 115 (1951) 13 pp.
- ³¹ F. J. Maier: Fluoridation of Public Water Supplies. *Journal of the American Water Works Association* (1951) **43**, p. 1120.
- ³² T. L. Hagan, U. S. Public Health Service: Private Communication.
- ³³ N. E. Jackson and E. A. Schmitt: The Washington Story of Fluoridation. *Water and Sewage Works* (1952) **99**, p. 435.
- ³⁴ T. J. Brice, H. G. Bryce, and H. M. Scholberg: Fluorochemicals—Today and Tomorrow. *Chemical Engineering News* (1953) **31**, p. 510.
- ³⁵ J. R. Callahan: Fluorine Industry Molds a Post-war Career from Wartime Service. *Chemical and Metallurgical Engineering* (1945) **52**, p. 94.
- ³⁶ E. M. Ott: Fluorine. *Chemical Engineering News* (1953) **31**, p. 1626.
- ³⁷ The Chememator: Not Enough Hydrofluoric. *Chemical Engineering* (1952) **59**, p. 112.
- ³⁸ K. D. Jacob, H. L. Marshall, D. S. Reynolds, and T. H. Tremearne: Composition and Properties of Superphosphate—Volatilization of Fluorine in Superphosphate Manufacture. *Industrial and Engineering Chemistry* (1942) **34**, p. 722.
- ³⁹ K. D. Jacob: *Fertilizer Technology and Resources in the United States*, Agronomy Monograph, Vol. III, Chap. 5. New York, 1953.

Analysis of Variables In Rod Milling

by Will Mitchell, Jr., C. L. Sollenberger,
T. G. Kirkland, and B. H. Bergstrom

SEVERAL constructive and fundamental studies have been made in the analysis of data obtained from experiments carried on with batch ball and rod mills. The operating characteristics of ball milling in small continuous circuits have also been appraised. It is from these analyses that some of the theories of comminution have been developed.

Relatively few studies of continuous rod milling have added significantly to the fundamental concepts, because seldom have they yielded sufficiently consistent results. Perhaps they have been too limited in their scope. Careful control of the variables in batch grinding is simple compared with that encountered in a continuous operation. This factor alone has discouraged many investigators. Occasionally results of systematic changes made in industrial rod mill circuits have been published, but usually the data are sketchy and are restricted because of the unwieldiness of the equipment used. The work, in general, has not been comprehensive; nevertheless it has provided empirical relationships that have bridged the gap between postulate and practice so that by proper manipulation of formulae, a mill designer can anticipate mill size and power requirements.¹⁻³ Although operating variables of a small continuous mill are not so easy to control as with the batch mill, with present day devices, and with careful experimental work, consistent results can be obtained.

Nearly four years ago, in the Process Laboratory, Allis-Chalmers Mfg. Co. began a systematic study of the effects of several variables upon the performance of the pilot rod mill. A mill was built in the laboratory to provide the versatility required for the proposed study. It was constructed in sections so that it could be operated, with a few modifications, as a rod mill 30 in. x 8 ft or 30 in. x 4 ft. The discharge end of the shell was flanged so that either an end peripheral discharge or an overflow discharge could be installed. Thus the performance of at least four types of mills could be studied merely by changing the type of discharge or the length of the mill shell.

The grinding experiments were designed so that a study could be made of the way in which the mill speed, feed rate, and pulp density influenced the performance of both overflow and end peripheral discharge rod mills. Four sets of experimental data were collected from the four mill arrangements. The mill in each set of experiments was fed at four rates of feed depending on the length of the mill, at four pulp densities, and at five percentages of critical speed. Electrical and mechanical controls were in-

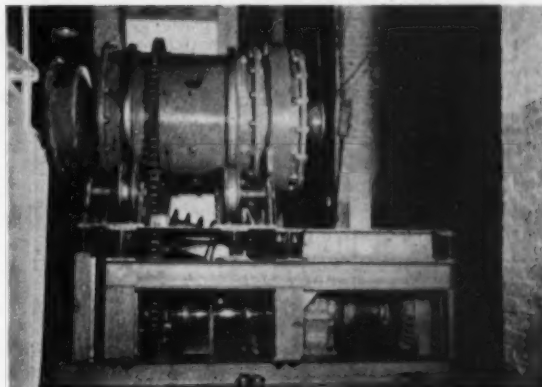


Fig. 1—A view of the 30-in. x 4-ft rod mill.

stalled to regulate all these independent variables, and auxiliary devices were used to verify the precision of the controls at each point. The dependent variables used to quantify the experiments were the reduction ratio and the new surface area produced as calculated from sieve analyses. These were incorporated with the energy factor by the calculation of both the new surface produced per unit of energy and the Bond work index.⁴ Rod wear, as a dependent variable, was not studied because of the short period of operation for each run.

Exclusive of repeat runs, each set of experiments yielded 80 products, and the total study at least 320 products, all of which were quantified. With the operating information collected, these data presented a bewildering accumulation. Statistical analysis has been invaluable in unraveling the confusion and in presenting a means of establishing the nature and the magnitude of the significant variables.

Data presented in this paper are those from the 30 in. x 4 ft end peripheral discharge rod mill, Fig. 1, when limestone was ground at feed rates of 1000, 2000, 4000, and 5000 lb per hr, at pulp densities of 50, 60, 70, and 80 pct solids, and at mill speeds of 50, 60, 70, 80, and 90 pct of the critical speed. These 80 tests have all been run at least twice, and occasionally a third time, to prove that the data obtained were reproducible. The techniques of operation and the methods of quantification of results are described in the following pages and the results analyzed statistically to show the significant variables. The variables are plotted to show the relationships that exist.

A massive dolomitic limestone from Waukesha Lime and Stone Co. was used for feed during these experiments because of its availability and its textural uniformity. This limestone analyzed 28.7 pct CaO, 21.0 pct MgO, 6.0 pct SiO₂, 0.4 pct Al₂O₃, and 0.3 pct Fe₂O₃, and had a loss on ignition of 44.1 pct. It had a rod mill grindability at 14 mesh of 9.6 grams per revolution from which a work index of 13.9 was calculated. The ball mill grindability at

W. MITCHELL, JR., C. L. SOLLENBERGER, T. G. KIRKLAND, and B. H. BERGSTROM, Members AIME, are with the Research Laboratories, Allis-Chalmers Mfg. Co., Milwaukee.

Discussion on this paper, TP 3901B, may be sent (2 copies) to AIME before Dec. 31, 1954. Manuscript, July 7, 1954. New York Meeting, February 1954.

100 mesh was 3.34 gpr, which is equivalent to a work index of 7.28. Work indices calculated from Bond grindabilities through all the mesh sizes from 14 mesh to and including 200 mesh showed that the work index decreased consistently as the grind became finer. Apparently this limestone is easier to grind in the finer sizes.

Preliminary tests showed that a $-\frac{3}{4}$ in. crushed stone as it was received from the supplier did not give a consistent sieve analysis; hence, a coarsely crushed stone was obtained from the quarry and a uniformly sized rod mill feed was prepared in the laboratory, see Fig. 2. Minus $1\frac{1}{2}$ -in. $+\frac{3}{4}$ -in. stone was received in 8-ton dump trucks and passed through a 2-in. grizzly onto a 20-in. conveyor belt. From the belt the stone was lifted by a bucket elevator and discharged into two 15-ton bins.

The bins were of the slanting-bottom type but had a horizontal square steel distribution plate located 3 ft above the discharge opening and 1 ft in from the four sides. This device allowed the material to flow from four directions into the bin discharge opening and eliminated the funneling through of feed from the vertical side. Sampling of the discharge from the bins showed no significant segregation, especially when the bins were maintained nearly full.

From the bins the stone was fed by means of electro-magnetic vibrating feeders to a Hydrocone crusher equipped with a $1\frac{1}{2}$ -in. eccentric and set at 0.4 in. close side. To check the crusher setting three lead slugs were passed through the chamber at least once an hour during the operating cycle. The slugs were collected from the discharge of the crusher and their thickness measured with a micrometer. When necessary, the crusher setting was adjusted.

The crusher produced a rod mill feed, 96.8 pct passing $\frac{3}{4}$ in., which was transferred by conveyor belt and bucket elevator into a third 15-ton bin similar to the ones described. Near the top and in the center of the rod mill feed bin, a Tellevel bin indicator was installed. Whenever the level of the stone settled below a certain point the indicator automatically activated the crushing circuit to produce more crushed stone until the bin was filled again. To minimize segregation, the rod mill feed bin was also equipped with a square steel distribution plate near the bottom.

An electromagnet feeder at the discharge opening of the bin conveyed feed into the hopper of a No. WL-2669 Merrick Feedoweight. A Tellevel indicator in the hopper activated the feeder at the discharge of the feed bin whenever the level of the feed in the hopper dropped sufficiently. The Feedoweight maintained a constant feed rate within 50 lb for any given setting. It was also equipped with a totalizer which measured the total amount of feed traveling on the feeder belt for any interval of time. The Feedoweight discharged into a curved spout which discharged into a drum feeder on the rod mill.

The product from the mill flowed down a launder to a spiral classifier. Classifier overflow was pumped to a thickener which discharged by gravity to a drum filter. The filter cake was discarded along with the classifier sands collected in hoppers.

The mill used in this investigation was 30 in. ID by 47 in. long. The shell was made from $\frac{1}{2}$ in. rolled plate and had eight half-round 1-in. radius lifters spaced evenly around the inside periphery. There were no liners in the mill. There were two riding rings on the exterior of the mill shell which sat in 1-ft diam flanged rollers, two on each side. The

rollers rotated on ball bearings on stationary stub shafts. The mill and the rollers were mounted on top of a fabricated steel platform. The motor drive was installed underneath the platform, see Fig. 1.

Power for the mill was supplied by a 25-hp, 220-v dc motor controlled by a rheostat so that the speed could be varied. The motor was connected to a Jones speed reducer, which gave a 6.20 ratio. The gear reducer was connected to a stub shaft through a Baldwin-Lima-Hamilton SR4 strain gage torque meter pickup, capacity 1000 ft-lb. A 14-tooth sprocket on the stub shaft was connected by a chain to a 66-tooth sprocket around the outside of the mill. The stub shaft was supported rigidly by two ball-bearing pillow blocks bolted to the mill frame.

All the experiments were conducted with a rod charge which filled 40 pct of the mill volume. The rods were cold drawn steel round stock which had a hardness of 134 Brinell and analyzed 0.26 pct C, 0.008 pct P, and 0.037 pct S. Spectrochemical analysis showed the presence of 0.55 pct Mn, 0.17 pct Si, 0.03 pct Ni, 0.02 pct Cr, 0.003 pct Mo, and 0.08 pct Cu. Twelve rods were of $2\frac{1}{2}$ in. diam, 22 of 2 in. diam, 32 of $1\frac{1}{2}$ in., and 46 of 1 in. All were $45\frac{1}{4}$ in. long. Total weight of the rod charge was maintained as near 2850 lb as possible. At regular intervals during runs the charge was removed and weighed. Any loss was compensated for by the addition of rods.

The mill was operated with eight 3-in. diam openings, spaced evenly around the periphery of the discharge end. The total discharge area was 0.42 sq ft.

The power demand of the mill was determined from torque and speed measurements. The output of the torque pickup was amplified and the amplified signal permanently recorded by an Esterline-Angus recording milliammeter. Calibration of the torque meter was accomplished by application of static loads to the meter shaft so that a curve relating the foot-pounds of torque to the milliammeter reading could be plotted. Because the measurement of power by means of the torque meter was a direct measure of power supplied to the stub shaft that drives the mill, no corrections for motor or gear reducer efficiencies were necessary. The power demand was also determined by means of an Esterline-Angus recording wattmeter, connected to measure the input power to the motor. The demand was read directly from the recorder but had to be corrected for motor efficiency at the various speeds used during the investigation.

To obtain the mill speed, an ac tachometer generator was connected directly to the outboard shaft of the motor, and the voltage generated was transmitted through a rectifying system and recorded on a dc recording voltmeter. The recording voltmeter was calibrated with a Berkeley Events Per Unit Time Meter so that the meter was read directly in revolutions per minute.

Water from a constant head tank was added to the mill through Flowrators which were set to give the proper amount of water for the pulp density required.

At the beginning of each group of tests the operator checked the circuit for mechanical fitness and the instruments for proper adjustment. A feed rate was established by careful regulation of the Feedoweight; then the water flow was set by means of the Flowrator to give the calculated pulp density. Rotational speed of the mill was adjusted with the rheostat until the specified percentage of critical speed was indicated on the time meter. Feed rates were checked by timed samples.

Table I. Data for Rod Mill with End Peripheral Discharge 30 In. x 4 Ft.

Test No. (Feed)	Feed Rate, Lb per Hr (Waukesha Limestone)	Mill Speed, Rpm	Pulp Density, Pct Solids	P ₈₀ Microns (F ₈₀ = 12,200)	K Intercept Microns (17,300)	M Slope (0.050)	Power Demand, Kw	Reduction Ratio	New Surface m ² × 10 ⁻³ Hr	Work Index, Kw-Hr Ton	New Surface Per Unit Energy m ² × 10 ⁻³ Kw-Hr
1	1000	24	50	78	106	0.295	3.93	156.4	112.4	7.59	28.6
2	1000	29	50	73	153	0.302	4.97	167.1	112.3	9.27	22.6
3	1000	34	50	63	144	0.270	5.42	193.6	116.2	9.35	21.9
4	1000	39	50	70	161	0.268	6.31	174.3	114.1	11.58	18.1
5	1000	44	50	78	173	0.280	7.76	156.4	112.5	14.91	14.5
6	1000	24	60	71	149	0.301	4.42	171.8	112.6	8.15	25.5
7	1000	29	60	63	152	0.253	5.50	193.6	117.1	9.47	21.3
8	1000	34	60	59	139	0.260	5.99	206.8	118.1	10.03	18.9
9	1000	39	60	57	148	0.234	6.99	214.9	116.6	11.01	17.4
10	1000	44	60	69	172	0.244	6.99	176.8	112.9	12.49	16.4
11	1000	24	70	63	147	0.263	4.42	193.6	117.8	7.62	26.6
12	1000	29	70	55	141	0.251	5.27	210.3	118.7	8.73	22.5
13	1000	34	70	53	141	0.228	5.85	230.2	118.0	9.24	20.2
14	1000	39	70	55	146	0.227	6.49	221.8	119.0	10.29	18.3
15	1000	44	70	62	159	0.237	7.87	196.8	116.4	13.35	14.8
16	1000	24	80	79	167	0.259	3.96	154.4	116.7	7.70	27.9
17	1000	29	80	70	175	0.244	5.46	174.3	113.0	9.94	20.7
18	1000	34	80	71	173	0.250	5.88	171.8	112.8	10.85	19.2
19	1000	39	80	66	175	0.229	6.94	184.8	113.0	12.24	16.3
20	1000	44	80	97	235	0.252	5.68	125.8	105.0	12.29	18.5
21	2000	24	50	353	668	0.350	3.68	34.6	129.5	8.67	33.3
22	2000	29	50	207	379	0.369	4.67	58.9	151.6	7.60	32.5
23	2000	34	50	165	316	0.343	5.71	73.9	169.1	8.28	29.6
24	2000	39	50	152	300	0.328	6.40	80.3	177.2	8.84	27.7
25	2000	44	50	187	360	0.341	7.12	65.2	160.7	11.21	22.6
26	2000	24	60	261	496	0.348	4.21	46.7	145.7	7.85	34.6
27	2000	29	60	178	529	0.353	5.01	69.7	164.8	7.47	32.9
28	2000	34	60	146	293	0.327	5.54	82.4	179.6	7.51	32.4
29	2000	39	60	136	280	0.309	6.11	89.7	187.8	7.90	30.8
30	2000	44	60	188	400	0.296	6.51	64.9	173.2	10.16	26.6
31	2000	24	70	253	513	0.316	4.12	48.2	153.3	7.62	37.2
32	2000	29	70	168	341	0.315	4.94	72.6	177.1	7.11	35.9
33	2000	34	70	139	281	0.317	5.78	87.8	186.7	7.55	32.3
34	2000	39	70	130	292	0.301	6.44	87.8	188.6	8.36	29.5
35	2000	44	70	194	423	0.286	6.35	62.9	175.7	10.04	27.3
36	2000	24	80	302	612	0.316	3.94	40.4	145.6	8.05	37.0
37	2000	29	80	202	419	0.306	4.83	60.4	168.8	7.80	34.8
38	2000	34	80	166	364	0.284	5.77	73.5	182.4	8.33	31.6
39	2000	39	80	182	414	0.279	6.41	67.0	177.8	9.70	27.8
40	2000	44	80	207	465	0.276	6.05	58.9	172.5	9.88	28.5
41	4000	24	50	2480	4650	0.355	3.70	4.9	124.0	16.23	33.6
42	4000	29	50	1603	2997	0.362	4.46	7.6	138.9	14.01	31.4
43	4000	34	50	782	1450	0.361	5.41	15.6	185.6	10.03	34.4
44	4000	39	50	603	1123	0.359	6.00	20.2	200.5	9.70	32.4
45	4000	44	50	1260	2570	0.313	6.39	9.7	178.3	16.90	28.0
46	4000	24	60	2850	5380	0.351	3.64	3.5	115.0	19.70	31.6
47	4000	29	60	1225	2106	0.383	5.00	10.0	143.0	12.81	28.7
48	4000	34	60	637	1173	0.385	5.80	19.2	193.7	9.58	33.4
49	4000	39	60	570	1070	0.354	6.08	21.4	215.1	9.11	35.4
50	4000	44	60	1225	2800	0.296	6.13	10.0	202.7	14.86	33.1
51	4000	24	70	3120	5840	0.356	4.11	3.9	107.1	23.51	26.1
52	4000	29	70	1831	3495	0.332	4.07	6.6	137.7	14.25	32.8
53	4000	34	70	1065	1940	0.372	4.94	11.5	159.3	11.25	32.5
54	4000	39	70	780	1500	0.341	6.00	15.6	196.7	11.10	32.8
55	4000	44	70	2123	4350	0.311	7.09	5.7	152.8	28.07	21.5
56	4000	24	80	2620	5120	0.333	3.98	4.7	127.8	19.18	32.2
57	4000	29	80	1635	3110	0.347	4.37	7.5	146.0	13.90	33.4
58	4000	34	80	813	1757	0.341	5.51	13.4	179.7	11.78	32.7
59	4000	39	80	770	1487	0.339	6.47	15.8	192.3	12.20	29.6
60	4000	44	80	1620	3450	0.295	6.74	7.5	132.5	21.93	19.7
61	5000	24	50	4717	8587	0.372	3.91	2.6	106.1	28.15	27.2
62	5000	29	50	3160	5733	0.375	5.09	4.0	124.9	22.74	24.6
63	5000	34	50	1320	2393	0.375	5.59	9.2	179.9	12.02	32.2
64	5000	39	50	1013	1853	0.370	6.60	12.0	195.6	11.76	29.7
65	5000	44	50	2817	5283	0.355	6.16	4.3	143.2	24.93	23.3
66	5000	24	60	4105	7500	0.370	4.11	3.0	109.9	26.54	26.1
67	5000	29	60	2963	4837	0.374	4.78	4.6	134.6	18.40	28.2
68	5000	34	60	1547	2847	0.366	5.87	7.9	175.8	14.23	30.0
69	5000	39	60	1250	2397	0.343	6.40	9.8	205.2	13.36	32.0
70	5000	44	60	2335	6360	0.346	6.10	4.7	139.3	29.41	22.9
71	5000	24	70	4475	8600	0.342	4.20	2.7	121.8	29.53	28.9
72	5000	29	70	3065	6005	0.332	4.59	4.0	153.8	20.31	32.6
73	5000	34	70	1917	3683	0.342	5.43	6.4	177.3	15.67	32.7
74	5000	39	70	1373	2650	0.339	6.45	8.9	201.2	14.27	31.3
75	5000	44	70	3320	6667	0.320	6.30	3.7	156.6	30.34	24.9
76	5000	24	80	4450	8500	0.345	4.37	2.7	124.2	29.48	28.4
77	5000	29	80	3273	6217	0.348	5.19	3.7	136.3	24.87	26.7
78	5000	34	80	2270	4283	0.350	5.84	5.3	160.3	19.56	27.8
79	5000	39	80	1700	3353	0.329	6.46	7.2	192.1	16.78	26.0
80	5000	44	80	3100	6167	0.324	6.28	3.9	157.8	28.08	25.1

After the circuit was operating satisfactorily, the conditions were maintained for 45 min to insure equilibrium within the mill. During this time the pulp density was roughly checked by means of the pulp balance. Following the 45-min interval the tapes on the recorders were marked and were collected over a 10-min period. Samples of the mill discharge were also collected during this period. Three samples weighing about 30 lb each were taken at 3-min intervals. The entire flow of pulp from the mill was collected in tared tubs or buckets

by removal of the launder between the mill and the classifier. Following this, a 40 to 50-lb timed sample of the entire flow of the feed was taken. The tests were continued by systematically changing the independent variables.

Table I contains the summary of the results of the 80 runs. The first three columns record the independent variables. The feed rate was obtained from the weights of the timed samples and the mill speeds were taken from the tape recording on the Events Per Unit Time Meter. Pulp densities were obtained

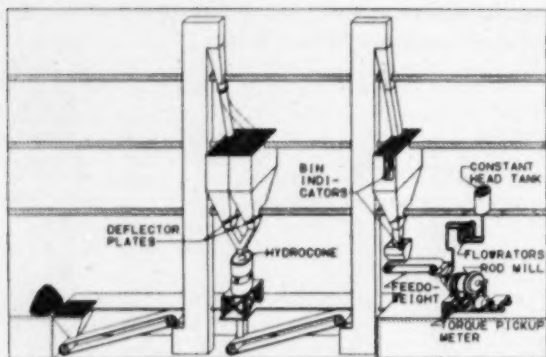


Fig. 2—Diagram of the crushing and rod milling circuit.

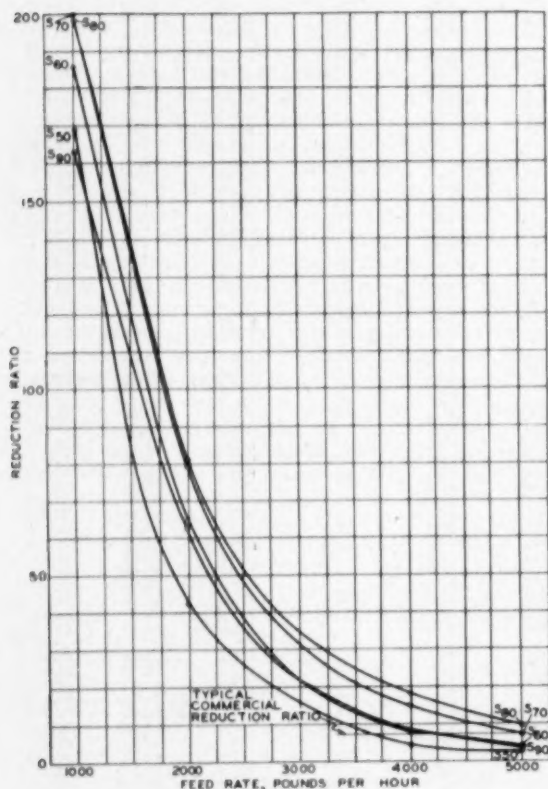


Fig. 3—Reduction ratio vs feed ratio for each mill speed. Averages for four pulp densities.

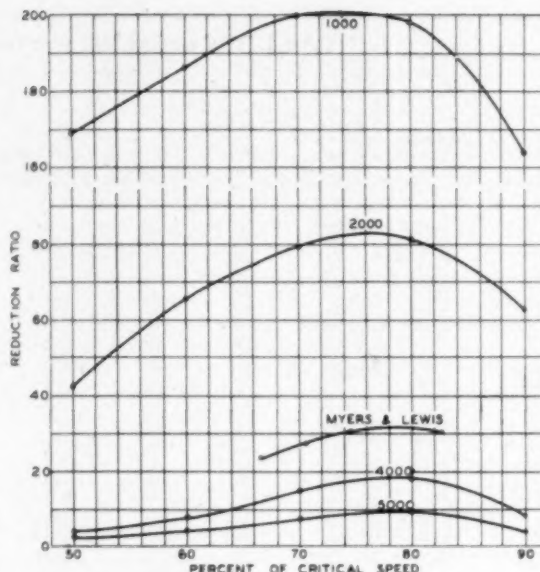


Fig. 4—Reduction ratio vs mill speed for each feed rate. Averages for four pulp densities.

from the samples of mill discharge that had been collected in tared buckets or tubs. The samples were weighed, dried, and weighed again to determine the moisture content. Average foot-pounds of torque was integrated on the torque meter tape by means of a planimeter. From these data, along with the speed, the power demands were calculated.

Dry sieve analyses of the feed samples and wet-and-dry analyses of the products were made. Results were plotted on log-log graphs with the log cumulative percent passing a given mesh as the ordinate and the log mesh size in microns as the abscissa according to the method described by Schuhmann.⁶ Feed and product analyses were plotted on each graph. From each curve the slope, K intercept, and the F_{80} or the P_{80} were obtained.

From these data the reduction ratio and the new surface produced were calculated. The energy requirement per unit of new surface produced and the Bond work index⁴ were also calculated, see Table I.

Surface areas were calculated from the sieve analyses according to the technique developed by Schuhmann⁶ and modified by Bond.⁶ Whether or not differences in the surface area of the feed and the product as calculated represent the absolute value of the new surface produced was considered incidental in this experiment, because only a measure-

Table II. Results of Variance Analyses. Three-Factor Analyses

Source of Variance	Components of Variance	Degrees of Freedom	Variance			
			Reduction Ratio	New Surface	Work Index	New Surface Per Unit Energy
F	$sd\sigma^2 + s\sigma_1\sigma^2 + d\sigma_1\sigma^2 + \sigma_0^2$	3	137,188.7	11,627.9	672.9	492.5
S	$fd\sigma_0^2 + f\sigma_0\sigma^2 + d\sigma_1\sigma^2 + \sigma_0^2$	4	1,506.2	6,378.8	153.4	128.4
D	$sf\sigma_0^2 + f\sigma_0\sigma^2 + s\sigma_1\sigma^2 + \sigma_0^2$	3	950.0	204.3	14.5	2.7
$F \times S$	$d\sigma_1\sigma^2 + \sigma_0^2$	12	250.3	853.6	48.4	23.6
$F \times D$	$s\sigma_1\sigma^2 + \sigma_0^2$	9	359.1	268.0	7.9	10.5
$D \times S$	$f\sigma_0\sigma^2 + \sigma_0^2$	12	24.3	85.8	3.3	6.8
Residual		36	25.1	70.0	2.4	4.0
Total		79				
Standard deviation			4.98	8.59	1.62	2.16
Relative deviation, pct			7.48	5.74	11.7	7.81

ment of the relative amount of work done during each test was desired for purposes of comparison.

Work indices were calculated from Bond's formula. This formula, as pointed out by R. A. Persson of the Process Laboratory at Allis-Chalmers, can also be derived from the general equation reported by Walker, Lewis, McAdams, and Gilliland.⁷ If n in their equation is replaced by $3/2$, an equation identical to the Bond work index formula can be derived. Thus an energy size reduction relationship which is halfway between the Kick and Rittinger relationships is obtained.

Variance analyses were made of reduction ratio, work index, new surface, and new surface per unit energy to determine whether or not feed rate, mill speed, or pulp density or an interaction of feed rate, mill speed, or pulp density significantly affected them. Variance is defined as the sum of the squares of the deviations of a set of observations above and below their mean, divided by the number of observations. In the analysis of variance, averages of data at one level of an independent variable are compared with the averages of data obtained at other levels, and it is possible with this statistical technique to show whether or not the variations are significantly greater than chance variation or experimental error. The procedure used has been described by Brownlee⁸ and by Dorenfeld.⁹

Variances obtained for the independent variables are shown on Table II. On this table, the letter F refers to feed rate, S to mill speed, and D to pulp density. The interactions of these variables are labeled FxS , FxD , and DxS . The residual variance is that portion of the total variability which cannot be attributed to the above factors or interactions, and is a measure of the experimental error. It may include a second order interaction, $FxDxS$. This interaction in a three-factor analysis is usually small. In testing the significance of the above variances, it has been assumed that the second order interaction does not exist or that it is not large. The components of variance, listed on Table II, aided in selecting tests of significance.

In calculating the variance of a finite sample, there is available only an estimate of the true mean of an infinite number of all possible results from which the sample is drawn. The sum of the squares of the deviations from the sample mean will be less than the sum of the squares of the deviations from the true mean. To correct for this and to obtain a better estimate of the variance, a divisor is used which is one less than the number of observations. This divisor is known as the degrees of freedom, see Table II.

The following general procedure was used for testing the significance of the variances shown on Table II. If a variance was less than the residual, it was considered nonexistent and was combined with the residual. DxS , FxD , and FxS were compared with the residual because these sources of variance included only the first order interaction and the residual. If the variance ratio reached 5 pct level of significance in tables of these ratios (95 pct certainty), the interaction was considered to have an effect; otherwise the variance attributed to the interaction was combined with the residual. At the 5 pct level the independent variable will have an effect on the dependent variable 95 times in 100.

The DxS interaction for each dependent variable was not significant, so it was combined with the residual. The FxS and FxD interactions, however,

Table III. Significant Variables. Three-Factor Analyses

Reduction Ratio	New Surface	Work Index	New Surface Per Unit Energy
F^*	F^*	F^*	F^*
S^{**}	S^{**}	S^{\dagger}	S^{\dagger}
FxS^{\dagger}	FxS^{\dagger}	FxS^{\dagger}	FxS^{\dagger}
FxD^{\dagger}	FxD^{**}	FxD^{**}	$FxD^{\dagger\dagger}$

* No test, but probably highly significant.

** Greater than 1 pct level.

† Greater than 0.1 pct level.

‡ Close to 5 pct level; may be significant.

§ 1 pct level.

|| Slightly greater than 5 pct level.

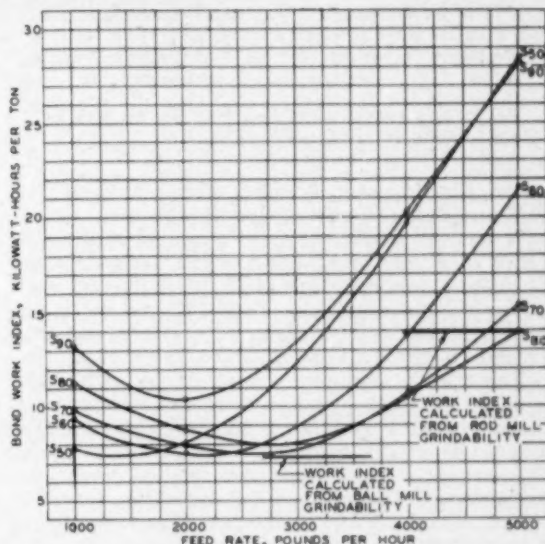


Fig. 5—Bond work index vs feed rate for each mill speed. Averages for four pulp densities.

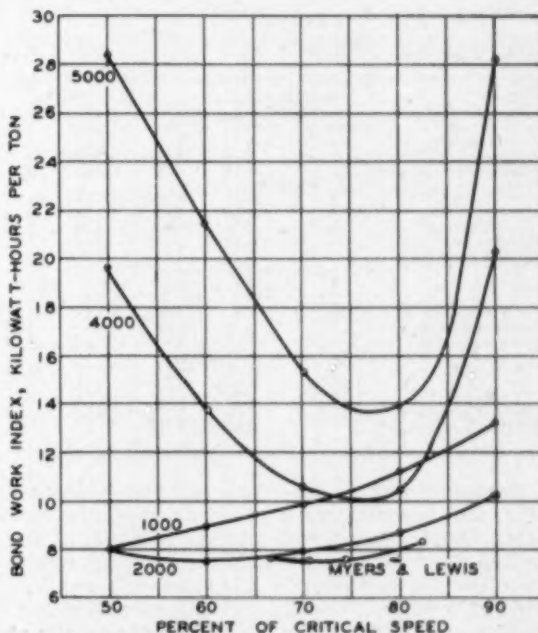


Fig. 6—Bond work index vs mill speed for each feed rate. Averages for four pulp densities.

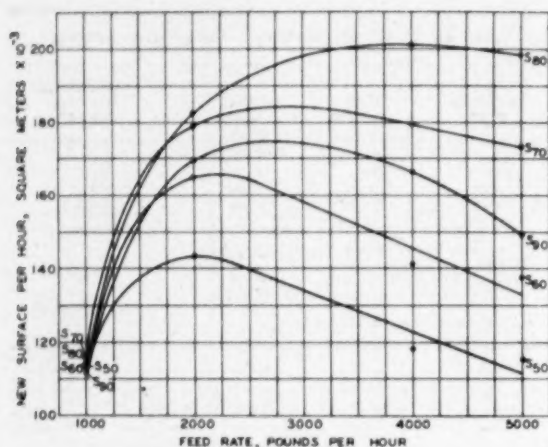


Fig. 7—New surface per hour vs feed rate for each mill speed. Averages for four pulp densities.

were. Consequently, S and D were compared with $F \times S$ and $F \times D$ respectively for significance.

It was not possible to make a test for the significance of F . However, because the variance attributed to F was large for all of the dependent variables, it appears that the effect of F must be significant in all cases. The significant variables and their levels of significance are shown on Table III.

The square root of the final combined residual was the standard deviation of any one experiment. These standard deviations, on Table II, show the magnitude of the error of the whole experiment. For comparisons of the error for one dependent variable with that of the other dependent variables, the relative deviation, or the deviation expressed as a percentage of the mean, is also shown.

Table IV. Results of Variance Analyses. Two-Factor Analyses

Source of Variance	Degrees of Freedom	Variance			
		$F_{1/2}$	F_1	F_2	$F_{2/2}$
Reduction Ratio					
S	4	1122.9	973.1	130.3	30.8
D	3	2434.9	171.9	17.2	3.2
Residual	12	77.4	18.9	2.3	1.0
Standard deviation		8.79	4.35	1.52	1.2
Relative deviation, pct		4.78	6.56	14.2	21.8
Work Index					
S	4	17.23	4.89	90.54	185.91
D	3	0.60	0.81	22.06	14.74
Residual	12	0.59	0.16	6.14	3.63
Standard deviation		0.772	0.399	2.48	1.91
Relative deviation, pct		7.48	4.7	16.5	8.9
New Surface					
S	4	18.3	956.4	4157.4	4107.6
D	3	44.9	290.7	837.3	135.3
Residual	12	3.1	11.2	207.8	73.6
Standard deviation		1.75	3.35	16.5	8.26
Relative deviation, pct		1.53	1.99	10.2	5.98
New Surface Per Unit Energy					
S	4	74.54	56.27	38.53	29.77
D	3	0.89	10.40	13.64	9.19
Residual	12	1.81	1.51	11.65	3.81
Standard deviation		1.28	1.229	3.47	2.21
Relative deviation, pct		6.22	3.94	11.2	7.81

Because it was not possible to test the significance of F , and because two interactions involving feed rate were significant, each analysis of variance was broken down into four two-factor analyses, one at each level of feed rate. In this manner it was possible to investigate the effect of mill speed and pulp density at each feed rate, and when the results at each level were compared with those at other levels, it was possible to determine how the effect of feed

rate depended on mill speed and pulp density and, conversely, how the effect of mill speed and pulp density depended upon feed rate. Table IV shows variances obtained and Table V significant factors.

Table V. Significant Variables. Two-Factor Analyses

Item	Reduction Ratio	New Surface	Work Index	New Surface Per Unit Energy
$F_{1/2}$	S^*	S^\dagger	S^*	S^*
F_1	D^*	D^*	S^*	S^*
F_2	S^{**}	D^*	D^\dagger	D^\dagger
$F_{2/2}$	S^*	S^*	S^\dagger	S^\dagger
	D^\dagger		D^\dagger	
	S^*	S^*	$D^{ }$	S^\dagger

* Greater than 0.1 pct level.

** Between 1 and 0.1 pct levels.

† Greater than 1 pct level.

‡ Between 5 pct and 1 pct levels.

§ 5 pct level.

|| Greater than 5 pct level.

Table V shows that pulp density was significant at several feed rates, whereas it was not significant in the three-factor analysis. Apparently this occurred because the magnitude of the variations resulting from changes in pulp density was small compared to the error for the entire experiment. With an analysis made at each level of feed rate, the variations attributed to pulp density became relatively more significant.

Significant Relationships

To determine what significant relationships were indicated by the variance analyses, the insignificant factor, density (three-factor analyses), was averaged out of the data, and curves were plotted of the dependent variables against feed rate for each level of mill speed, and against speed for each level of feed rate. To investigate the interactions of feed rate and mill speed, and feed rate and pulp density, the dependent variables were examined at each level of feed rate to determine how they varied with mill speed and pulp density when these independent variables were found to be significant (two-factor analyses). When an independent variable was not significant, it was averaged out of the data and the averages were examined for the relationship with the significant variable.

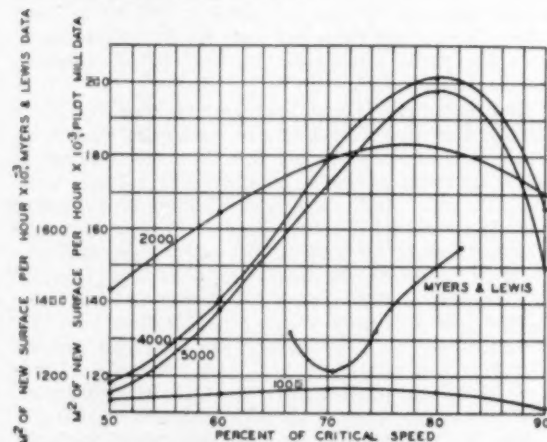


Fig. 8—New surface per hour vs mill speed for each feed rate. Averages for four pulp densities.

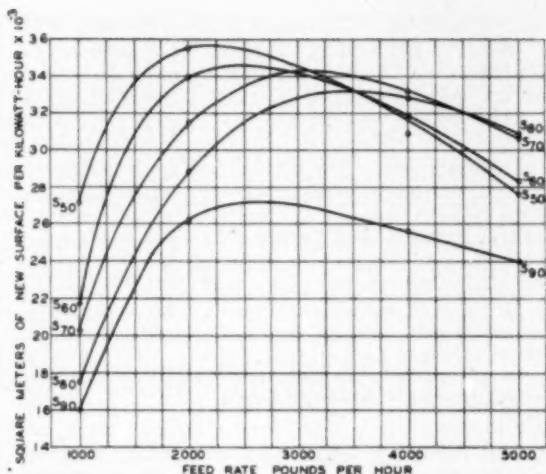


Fig. 9—New surface per kilowatt-hour vs feed rate for each mill speed. Averages for four pulp densities.

Reduction Ratio: Reduction ratio has been plotted against feed rate and speed on Figs. 3 and 4. Reduction ratio decreased rapidly as feed rate was increased, reaching maximum in the range of 70 to 80 pct of critical as the speed was increased. The $F \times S$ interaction can also be seen on these two figures. As feed was increased from 1000 to 5000 lb per hr, mill speed at which the maximum reduction ratio was obtained increased from 70 to 80 pct of critical.

The effect of the $F \times D$ interaction cannot be seen on these two curves because pulp density has been averaged out of the data. In Table V, density was found to be significant at all levels of feed rate except at 5000 lb per hr, and the $F \times D$ interaction was shown to be significant on Table III. To comprehend this interaction, the original data on Table I were examined. It was found that at 1000 lb per hr the reduction ratio was maximum at a pulp density of 70 pct solids; at 2000 lb per hr, between 60 and 70 pct solids; and at 4000 lb per hr, at 60 pct solids. The effect of pulp density on reduction ratio at 5000 lb per hr was not significant, but at speeds of 70 and 80 pct of critical, definite maximums were obtained at 50 pct solids. Apparently as feed rate was increased from 1000 to 5000 lb per hr, the pulp density at which maximum reduction occurred was more dilute, from 70 pct solids at 1000 lb per hr to 50 pct solids at 5000 lb per hr.

A horizontal line corresponding to a typical commercial reduction has been drawn on Fig. 3. This reduction ratio, 7.3, corresponds to a reduction from 80 pct passing $\frac{1}{2}$ in. to about 80 pct passing 10 mesh. At 50 pct of critical speed, this ratio could be obtained with a feed rate of about 3700 lb per hr; at 60 pct of critical speed, with a feed rate of about 4300 lb per hr; at 70 pct of critical speed, with a feed rate of 5000 lb per hr; and at 80 pct of critical, a feed rate greater than 5000 lb per hr would be necessary. In other words, for each 10 pct increase in the percentage of critical speed between 50 and 80, capacity increased roughly 15 pct.

Bond Work Index: Work index has been plotted against feed rate and speed on Figs. 5 and 6. The work index was at a minimum at feed rates from 1500 to 3000 lb per hr, depending upon the speed of the mill. It was at a minimum at speeds from 50 to 80 pct of critical, depending upon the feed rate. These curves show the $F \times S$ interaction in that as the

feed rate was increased from 1000 to 5000 lb per hr, the speed required to obtain minimum work index increased from 50 to 80 pct of critical.

It was again necessary to resort to the original data to identify the $F \times D$ interaction. Pulp density was shown on Table V to have a significant effect at all feed rates except at 1000 lb per hr. At 2000 lb per hr minimum work index was obtained at 60 to 70 pct solids; at 4000 lb per hr, 50 to 60 pct solids; and at 5000 lb per hr, at 50 to 60 pct solids. Apparently as the feed rate is increased, the pulp density in the mill should be more dilute to obtain minimum work index.

The lowest work index for all operating conditions investigated was 7.5, which was obtained at 2000 lb per hr, at 60 pct of critical speed. The reduction ratio with these conditions was 65.4, which represents a reduction from 80 pct passing $\frac{1}{2}$ in. to about 80 pct passing 65 mesh. This work index is practically the same as that calculated from the ball mill grindability at 100 mesh. A work index almost identical to that calculated from the rod mill grindability at 14 mesh, 13.9, was obtained at a feed rate of 5000 lb per hr and at 80 pct of critical speed. The reduction ratio with these conditions was 9.5, which is similar to the ratio obtained in many commercial installations.

For a reduction ratio of 7.3 (the ratio at which a 15 pct increase in capacity was noted with each 10 pct increase in the percentage of critical speed), the following work indices are indicated by the curves of Fig. 5. At 50 pct of critical speed and 3700 lb per hr, a work index of 17.0 is indicated. At 60 pct of critical and 4300 lb per hr, a work index of 15.8 is shown. At 70 pct of critical and 5000 lb per hr, a work index of 15.3 is shown. It appears that the increased capacity with increased speed was obtained at a greater efficiency.

New Surface: Figs. 7 and 8 show the effect of feed rate and mill speed on the production of new surface per hour. Maximum production of new surface per hour was obtained at feed rates from 2000 to 4000 lb per hr depending upon the mill speed. In the range corresponding to commercial rod milling

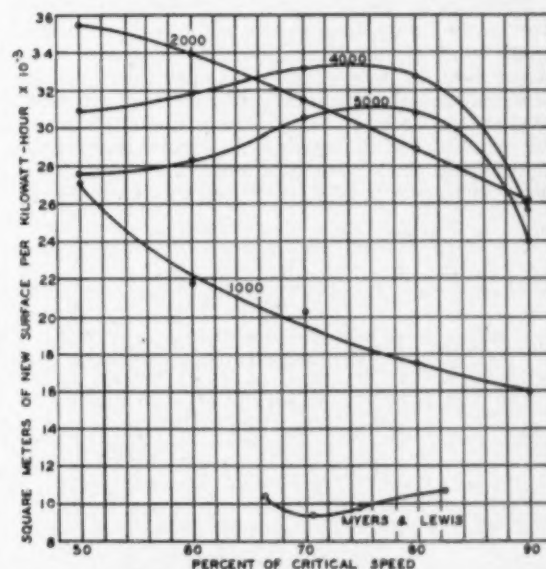


Fig. 10—New surface per kilowatt-hour vs mill speed for each feed rate. Averages for four pulp densities.

(feed rates of 3700 to 5000 lb per hr or more), it can be seen that the production of new surface decreased as the feed rate was increased. New surface was a maximum at speeds of 70 to 80 pct of critical depending upon the feed rate. Apparently the mill speed should be increased to 80 pct of critical as the feed rate is increased, for maximum production of new surface.

In Table V pulp density was found to be significant only at feed rates of 1000 and 2000 lb per hr. An examination of the experimental data for these significant effects revealed that at both 1000 and 2000 lb per hr, maximum production of new surface was obtained between 60 and 70 pct solids. Apparently the significant $F \times D$ interaction was only an indication that D was significant at 1000 and 2000 lb per hr, but not at 4000 and 5000 lb per hr. Even at low feed rates, the variation of new surface per hour with pulp density was small, so in general it can be said that the production of new surface was not greatly influenced by variations in the pulp density.

New Surface Per Unit Energy: New surface per unit energy has been plotted against feed rate and mill speed on Figs. 9 and 10. Maximum production of new surface per kilowatt-hour was obtained at feed rates from 2000 to 3500 lb per hr depending upon the mill speed. With this dependent variable, as with new surface, in the range of feed rates corresponding to commercial rod milling, the production of new surface per unit energy decreased as the feed rate increased. Maximum production of new surface per unit energy was obtained at 50 to 80 pct of critical speed depending upon the feed rate. The significance of the $F \times S$ interaction (Table III) is explained by the fact that as the feed rate was increased from 1000 to 5000 lb per hr, maximum production of new surface per kilowatt-hour was obtained at higher percentages of critical speed.

Pulp density was shown on Table V to be significant only at a feed rate of 2000 lb per hr. At this feed rate, maximum production per unit energy occurred at 60 to 70 pct solids, and the $F \times D$ interaction was significant only because the density effect reached significance at the 2000 lb per hr feed rate.

Variation of Work Index with Product Size: It was previously noted that the work index, calculated from Bond grindabilities for the Waukesha limestone used in this experiment, decreased as the product size decreased. In the factorial experiment, product size decreased with feed rate and the greatest variation for all dependent variables was attributed to feed rate. With most materials tested by the Bond grindability, the work index has either re-

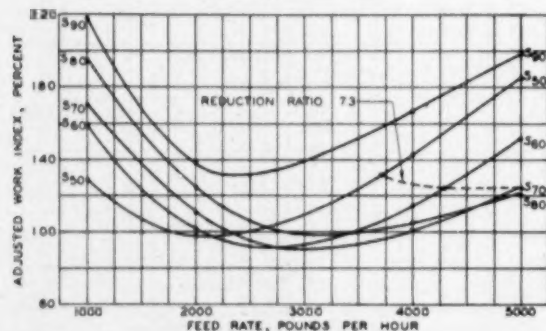


Fig. 11—Adjusted work index vs feed rate for each mill speed. Averages for four pulp densities.

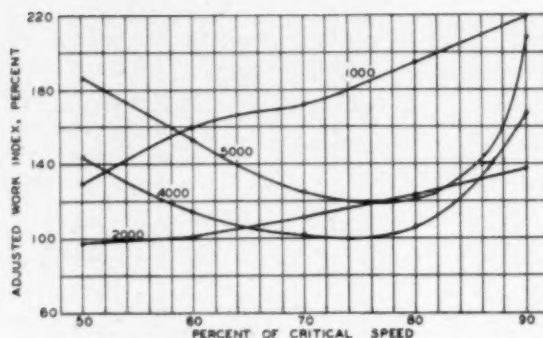


Fig. 12—Adjusted work index vs mill speed for each feed rate. Averages for four pulp densities.

mained relatively constant as the product size decreased or it has increased slightly.²⁰ To determine whether or not the use of Waukesha limestone, with its characteristic of being easier to grind in the finer sizes, in any way invalidated the experiment or led to erroneous conclusions, the work index for this material determined by Bond grindabilities was plotted against product size. From this curve, the expected work index was obtained for the product size for each of the 80 runs of the experiment. The pilot mill data were then divided by the corresponding expected work index to remove the variation of work index with product size from the data.

A variance analysis was made of the normalized work indices. The same factors were found to be significant in this analysis as were found in the previous one. However, the relative deviation was more than double the previous value. This occurred probably because the removal of the variation with product size, formerly attributed to feed rate, decreased the total known variation and made the unknown variation or error relatively more important.

Because there was no test for F in the three-factor analysis, the analysis was broken down as before into four two-factor analyses, one at each level of feed rate. The only differences between these results and the results of the previous two-factor analyses for work index were: 1—there were greater relative deviations, and 2—less significance could be attributed to pulp density.

Density was averaged out of the normalized work index data and the averages were plotted against feed rate and mill speed. These curves are shown on Figs. 11 and 12.

Work index was a minimum at feed rates from 2000 to 3300 lb per hr depending upon the mill speed. As the feed rate increased, the speed at which the minimum occurred increased from 50 to 80 pct of critical. Minimum work index appeared to occur at more dilute pulps as the feed rate increased from 70 pct solids at 1000 lb per hr to 50 pct solids at 5000 lb per hr. However, the effect of pulp density only reached significance at 5000 lb per hr. Lowest work index for all operating conditions investigated was indicated at about 2700 lb per hr and at 60 pct of critical speed. This was a slightly higher feed rate but the same speed found from the unadjusted data.

An examination of Fig. 11 shows that for a reduction ratio of 7.3, the ratio at which a 15 pct increase in capacity was noted with each 10 pct increase in the percentage of critical speed, the work index appears to decrease slightly as the higher capacity at

this reduction ratio is realized. At least no decrease in efficiency is obtained as capacity is increased.

It appears that the use of Waukesha limestone with its characteristic of being easier to grind in the finer sizes has not invalidated the general conclusions drawn from this experimental work.

Reference to Published Data: A comparison was made between the results of this experiment and data presented by Myers and Lewis¹¹ who ground a copper ore from -1 in. to -10 mesh in open circuit in a 6x9-ft overflow rod mill at a pulp density of 79 pct solids. In the Myers and Lewis experiments, mill speed was varied from 66.5 to 82.4 pct of critical but all other conditions were held constant. Their data have been plotted against speed, see Figs. 4, 6, 8, and 10. Curves having a configuration similar to those obtained from this investigation were obtained for reduction ratio and work index, but the new surface and new surface per unit energy curves differed somewhat. Maximum reduction ratio occurred at about 80 pct of critical speed, and minimum work index occurred at 70 pct of critical speed. Minimum values were obtained at 70 pct of critical speed for new surface and new surface per unit energy, and these variables continued to increase at 80 pct of critical speed. Differences in some of the curves may perhaps be attributed to the difference in the type of mill discharge or to disparity in mill size.

Conclusions

The data presented in this paper were obtained from an experiment carried on in a relatively small rod mill grinding a limestone, and the relationships found may or may not be entirely representative of those prevailing in the large mills used in industry. Nevertheless, a comparison with published data for a 6x9-ft rod mill showed similar variations with speed, at least in regard to reduction ratio and work index.¹¹ It would seem reasonable that many of the principles involved in continuous open circuit grinding would be applicable irrespective of the size of the mill, and that only the magnitude of the relationships would differ.

In general, the effect of pulp density was not very great. Feed rate and mill speed were much more significant. However, the results showed that as the feed rate to the mill was increased, it was necessary to operate the mill with a more dilute pulp, 70 pct solids at 1000 lb per hr to 50 pct solids at 5000 lb per hr, to obtain the greatest reduction and the lowest work index. The effect of pulp density on the production of new surface and new surface per unit energy was seldom significant. At a few feed rates, however, maximum production of new surface was obtained between 60 and 70 pct solids.

It was found that as the feed rate to the mill increased, the mill should be operated at higher speeds up to 80 pct of critical to obtain maximum reduction, maximum production of new surface, minimum work index, and maximum production of new surface per unit energy.

The most efficient operating conditions for this rod mill occurred at a feed rate of 2000 lb per hr, a speed of 60 pct of critical, and a pulp density of 60 to 70 pct solids. With these conditions the work index was 7.5 and the reduction ratio was 65.4. When the data were adjusted to remove the variation in work index with product size, the most efficient conditions indicated by the adjusted data were a feed rate of 2700 lb per hr, and the same speed and pulp density indicated by the unadjusted data.

With these conditions the work index was about 8.1 and the reduction ratio was about 30 (both figures obtained by interpolation). The product in either case was finer (80 pct passing 65 mesh or 80 pct passing 35 mesh) than that usually obtained from a commercial rod mill. These results indicate that on many ores the rod mill could probably be used to grind efficiently to finer product sizes than those ordinarily made in commercial operations. These results also suggest that further experimental work should be done to investigate the effect of increased feed size to the mill at these same operating conditions until a product as coarse as -8 or 10 mesh would be obtained.

In the range of feed rates at which a product size corresponding to a commercial rod mill reduction ratio of 7 to 10 was obtained, it was found that for each 10 pct increase in the percentage of critical speed between 50 and 80 pct, a corresponding increase in capacity of roughly 15 pct was realized at slightly increased efficiency. Best operating speed in this range of commercial reduction ratio was 80 pct of critical, best pulp density was 50 pct solids, and the work index was about 14.0 at a feed rate of 5000 lb per hr. This work index was practically the same as that calculated from a Bond rod mill grindability on the limestone at 14 mesh.

Whether the rod mill should be operated at the conditions which would give the lowest work index (7.5 to 8.1), or whether it should be operated at conditions which would give reduction ratios similar to those obtained in many commercial operations (7 to 10), is probably a matter of the economics of production costs compared with capital investment.

Acknowledgments

The authors acknowledge with thanks the assistance given by H. Wurcer, F. F. Miskell, E. O. Schneider, and L. E. Aguirre of the Process Section and by members of the Analytical, Metallurgical, Mechanical, and Physics Sections of the Research Laboratories. They also express thanks to J. B. Calkins, formerly with the Process Section and now with The Zonolite Co., and H. K. Ihrig, Vice President in Charge of Research, Allis-Chalmers Mfg. Co., for assistance in the preparation of the manuscript.

References

- ¹S. D. Michaelson: Determination of Ball Mill Size from Grindability Data. *Trans. AIME* (1945) TP 1844.
- ²F. C. Bond and W. L. Maxson: Grindability and Grinding Characteristics of Ores. *Trans. AIME* (1939) 134, p. 296.
- ³F. C. Bond, S. D. Michaelson, J. F. Myers: Rod-Milling Plant and Laboratory Data. *Trans. AIME* (1947) TP 2175, 11 pp.
- ⁴F. C. Bond: Third Theory of Comminution. *Trans. AIME* (1952) 193, pp. 484-494.
- ⁵R. Schuhmann, Jr.: Principles of Comminution, I—Size Distribution and Surface Calculations. *Trans. AIME* (1940) TP 1189, 11 pp.
- ⁶F. C. Bond: Measuring Surface Area in Grinding. *Trans. AIME* (1941) TP 1296, 7 pp.
- ⁷W. H. Walker, W. K. Lewis, W. H. McAdams, and E. R. Gilliland: *Principles of Chemical Engineering*, pp. 254-255. McGraw-Hill Book Co., New York, 1937.
- ⁸K. A. Brownlee: *Industrial Experimentation*. Chemical Publishing Co., New York, 1949.
- ⁹A. C. Dorenfeld: Five Variable Flotation Tests Using Factorial Design. *Trans. AIME* (1951) 190, p. 1073.
- ¹⁰F. C. Bond: Work Indexes Tabulated. *Trans. AIME* (1953) 196, pp. 315-316.
- ¹¹J. F. Myers and F. M. Lewis: Effects of Rod Mill Speed at Tennessee Copper Company. *Trans. AIME* (1949) TP 2585B, 2 pp.

A reminder that natural abrasives find an important place in modern industry. Various deposits of commercial value await mining operations in Canada.

Natural Abrasives in Canada

by T. H. Janes

NATURAL abrasives of some type are found in all countries of the world. In order of their hardness the principal natural abrasives are diamond, corundum, emery, and garnet, which are termed *high grade*, and the various forms of silica, including pumice, pumicite, ground feldspar, china clay and, most important, sandstone.

The properties qualifying materials for use as abrasives are hardness, toughness, grain shape and size, character of fracture, and purity or uniformity. For manufacture of bonded grain abrasives such as grinding wheels, the stability of the abrasive and its bonding characteristics are also important. No single property is paramount for all uses. Extreme hardness and toughness are needed for some applications, as in diamonds for drill bits, while for other purposes the capacity of the abrasive to break down slowly under use and to develop fresh cutting edges is of greatest importance, as with garnet for sandpaper. In dentifrices, soaps, and metal polishes, of course, hardness and toughness are objectionable.

First among the natural abrasives, **industrial diamonds** are essentially of three types: 1—*bort*, which includes off-color, flawed, or broken fragments unsuitable for gems; 2—*carbonado*, or black diamond, a very hard and extremely tough aggregate of very small diamond crystals; and 3—*ballas*, a very hard, tough globular mass of diamond crystals radiating from a common center. Bort comes from all diamond-producing centers, carbonados only from Brazil, and ballas chiefly from Brazil, although a few of this last group come from South Africa. By far the largest producer of industrial diamonds is the Belgian Congo; the Gold Coast, Angola, the Union of South Africa, and Sierra Leone supply most of the remainder. There is no production in Canada, which imports \$6 to \$9 million worth of industrial diamonds annually.

Industrial diamonds find innumerable uses in modern industry. They are used for diamond drill bits for the mining industry; in diamond dies for wire drawing; in diamond-tipped tools for truing abrasive wheels and for turning and boring hard rubber, fibers, and plastics; and in diamond-toothed saws for sawing stone, glass, and metals. High-speed

tool steels, cemented carbides, and other hard, dense alloys can be cut, sharpened, or shaped efficiently only with diamond-tipped tools and diamond grinding wheels.

Second only to the diamond in hardness is **corundum**, an impure form of the ruby and sapphire gems consisting of alumina and oxygen (Al_2O_3) with impurities such as silica and ferric oxide. Corundum generally crystallizes from magmas rich in alumina and deficient in silica, as in the nepheline syenites of eastern Ontario. Grain corundum is used in the manufacture of grinding wheels; very coarse grain is used in *snagging* wheels. Both types of wheels are employed in the metal trades, where the hardness of corundum, coupled with its characteristic fracturing into sharp cutting edges, makes it an ideal cutting tool. The finest corundum (flour grades) is used for fine grinding of glass and high-precision lenses.

From 1900 to 1921 Canada was the world's leading producer of corundum. Following this period the deposits located in northern Transvaal of the Union of South Africa supplied more and more of the world's requirements, and since 1940 South Africa has provided almost the entire output, which has ranged between 2500 to 7000 tons a year during the last decade. Minor amounts have also been produced in Mozambique, India, and Nyassaland.

Opportunities for Mining Corundum

Corundum deposits in southeastern Ontario are of three types, which may be described as follows:

1—Scattered, irregularly-shaped deposits of coarse-grained corundum which could be mined by means of small pits. About 10 groups of such deposits are known. Although the tonnage of individual deposits of this type is not great, it has been estimated that several years' ore supply is available for a small tonnage operation. Deposits average about 9 pct corundum.

2—Large irregular deposits of coarse-grained corundum which would require mining by adit with possibly a scavenger operation on the remains of former surface deposits. The Craigmont deposit of this type produced about 20,000 tons of corundum concentrate during operations between 1900 and 1913. Most of the readily available surface ore was removed by operators during that time. Reserves of ore above road level have been estimated to average 7 pct corundum, but none of the so-called reserves have been blocked out, or even indicated, by diamond drilling. From 1944 to 1946, 2025 tons of

T. H. JANES is Engineer, Industrial Minerals Div., Mines Branch, Ottawa, Ont.

Discussion on this paper, TP 3899H, may be sent (2 copies) to AIME before Dec. 31, 1954. Manuscript, Jan. 21, 1954. New York Meeting, February 1954.

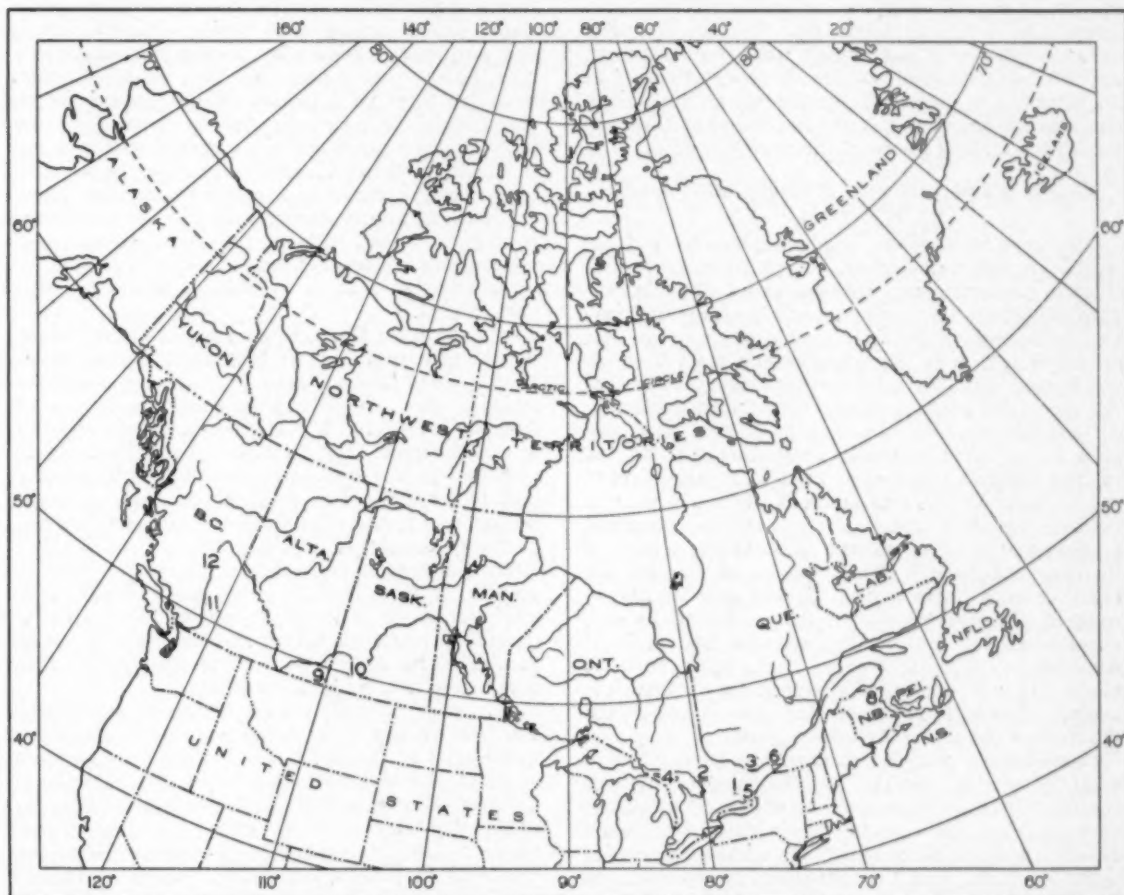


Fig. 1—Locations of natural abrasives in Canada are indicated by numbers 1 through 12 as follows. 1—Corundum, Craigmont. 2—Garnet, River Valley. 3—Garnet, Labelle. 4—Quartzite, Manitoulin. 5—Sandstone, Joyceville. 6—Sandstone, St. Canut. 7—Grindstones, Sackville. 8—Grindstones, Clifton. 9—Grinding pebbles, Elkwater Lake. 10—Pumicite, Waldeck. 11—Pumicite, Deadman River. 12—Diatomite, Quesnel.

corundum were recovered from the tailings of former operations that averaged 2.96 pct corundum.

3—A large body of fine-grained corundum, averaging about 5 pct corundum, disseminated throughout a nepheline-feldspar-mica gneiss. A considerable tonnage of this material is available in the Monteagle deposit near Bancroft, and in 1951 tests for the separation and recovery of corundum, nepheline, and muscovite mica were undertaken by Ortona Gold Mines Ltd.

The southeastern Ontario corundum-bearing zones may be divided roughly into three belts: the main or northern belt, the Methuen-Burleigh or middle belt, and the Lanark-Frontenac or southern belt. The rocks comprising these belts are, in general, of four types, but in many cases one type merges into another. Corundum-bearing rocks in the northern belt are syenites, syenite-pegmatites, nepheline syenites, and anorthosites. It is believed that corundum is one of the last constituents to crystallize out from the molten magma and that the whole of the excess of the alumina separates out as corundum, provided that the iron, magnesia, and silica present are low. Corundum does not occur in the immediate vicinity of free silica.

Canadian imports of graded grain corundum, according to the Dominion Bureau of Statistics,

amounted to 162 tons valued at \$43,450 in 1953 compared to 125 tons valued at \$31,066 in 1952.

In northern Transvaal individual deposits vary widely in size but are invariably associated with pegmatite intrusions into basic rocks. Until recent years most of the production has been obtained from eluvial deposits resulting from weathering of pegmatites where the corundum is recovered by hand-cobbing or by gravity separation methods. Recovery from reef deposits is usually confined to those in which the rock has been weathered. After crushing the corundum is recovered as outlined above. Boulder corundum, carrying 60 to 70 pct corundum, undergoes no treatment before shipment other than breaking into sizes convenient for bulk handling. Many deposits of corundum occur in Southern Rhodesia, Nyassaland, and Mozambique. The price of corundum concentrate varies between \$85 to \$110 per ton according to grade. A minimum corundum (Al_2O_3) content of 90 pct is desired.

Emery is an intimate mixture of corundum and magnetite, with or without hematite, varying in hardness and toughness according to the amount of iron oxides present. Emery is massive, nearly opaque, and dark gray to blue-black with a reddish tinge depending on the amount of hematite present. It usually occurs in crystalline limestones and

schists, often with chlorite in hornblende schists in association with peridotite and diorite. The iron oxide is physically inseparable from the corundum, and while it detracts from the efficiency of emery as an abrasive, it adds to its polishing action. Grain shape of the emery is more or less round and for this reason the cutting action of the emery is slight.

Grades of Emery, Sources of Supply, and Imports of Canada

The three main emery-producing countries of the world are Greece, Turkey, and the United States. Grecian (Naxos) emery contains about 65 pct corundum and about 25 pct magnetite. In corundum content and quality Turkish emery approaches that produced in Greece. American emery, most of which comes from the state of New York, is the softest of the three and contains about 45 pct iron oxides.

Canadian imports of emery powder, grains, and grits for abrasive purposes were valued at \$95,110 in 1953 compared to \$54,566 in 1952. A large part of the U. S. production of about 5000 tons a year is used in concrete and asphalt floors in industrial plants because of its marked resistance to wear and its non-skid nature. The balance of the output, together with imports from Greece and Turkey, is used in abrasive products such as coated papers, abrasive sticks, and grinding wheels. The price of American first-grade emery, f.o.b., New York, is about \$12 per ton. Grain emery, f.o.b., Pennsylvania, is quoted at 10¢ per lb for Turkish and Naxos grain, 6½¢ per lb for American grain.

Garnet is the name given a certain group of minerals possessing similar physical properties and crystal forms although their chemical compositions vary widely. The garnet group comprises seven different species, all of which are silicates of aluminum, calcium, iron, magnesium, manganese, or chromium, the different metals being replaceable one by the other. The garnets may vary widely in color, but almandite (iron aluminum silicate), the commonest, and andradite (calcium iron silicate) range in color from deep red through brown to black.

Garnets occur as accessory minerals in a large variety of rocks all over the world but are particularly common in gneisses and schists. When they are present in sufficient quantities the rocks are designated as garnet gneisses or schists. They also occur as contact metamorphic deposits in crystalline limestones, pegmatites, serpentines, and other rocks. Hornblende and mica are the usual associated minerals, quartz, feldspar, and pyroxene being present in lesser amounts. Garnets are *high-temperature* minerals and are usually found around intrusive contacts or vein deposits of high-temperature origin. Because of their resistance to weathering and erosion, garnets are often found as a detritus of crystals in the immediate vicinity of the original rocks, or as rounded grains in river or sea sands.

Garnet in the World Market

Although garnet is a common constituent of rocks, large workable deposits suitable for manufacture of garnet paper and cloth are scarce. Commercial production of this type of garnet has been confined chiefly to the United States, and even here successful operations on a large scale have been limited to one area in New York State. New York almandite garnet has incipient lamellar parting planes which cause it to break into thin, sharp-edged plates. This unique physical property renders it the world-

standard garnet for manufacture of garnet paper and cloth. Other garnets may possess equal toughness and be just as suitable for less important abrasive uses, but generally they are not acceptable substitutes for New York garnet. World production and consumption of garnet for this use ranges from 7000 to 9000 tons a year, and this together with competition from artificial abrasives has severely restricted the search for garnet and the development of known deposits. In recent years garnet has been recovered from garnet sands in Idaho for use in the sandblasting and metal spraying industries. About 4000 tons were reported sold in the United States for these uses in 1951.

In New York State, Barton Mines Corp. mines a deposit of garnet on Gore Mountain, 5 miles west of the village of North Creek. The orebody is described as being about ¾ miles long and varying in width from 50 to 300 ft. The almandite garnet occurs in a metamorphic rock in which hornblende is the principal gangue mineral, associated with feldspars and hypersthene and smaller amounts of apatite, biotite, and pyrite. The garnet occurs mostly as imperfectly developed crystals varying from a fraction of an inch to more than a foot in diameter and constitutes from 5 to 20 pct of the orebody, which averages about 10 to 12 pct garnet. The ore is removed by quarry benching methods and the garnet recovered by a sink-float separation, ferro-silicon being used as the heavy medium.

Canadian production of garnet has been negligible. There are many occurrences in gneisses and schists in all parts of Canada, but the garnets are generally of small size and badly fractured. Niagara Garnet Co. Ltd., Sturgeon Falls, Ont., intermittently operates a deposit near River Valley in which crystals range in size from marbles to those of 4-in. diam. Open-cut methods are used for mining. After preliminary crushing the material is passed through trommel screens, and the oversize, carrying about 60 pct garnet, is trucked to the mill at Sturgeon Falls for further crushing, concentration, and sizing. Minor amounts of garnet grain and flour grades of garnet have been marketed during recent years. The garnets occur in gneiss associated with hornblende, and flake mica constitutes the main accessory mineral. Several years ago a high-grade garnet occurrence in massive pyrrhotite was mined near Labelle, Que. The deposit was of minor extent and was quickly mined out.

Probably about 90 pct of the garnet produced is employed for the manufacture of abrasive-coated papers and cloths. The remainder is used in the form of loose grains for surfacing and polishing relatively soft stones, for some metal-spraying and sandblasting operations, and in minor amounts for surfacing plate glass.

Garnet production in the United States in 1951, as reported by the U. S. Bureau of Mines, reached an all time high of 14,050 short tons, valued at \$1,246,947. The three Canadian manufacturers of coated paper and cloth use about 450 tons of graded garnet grain annually.

The current price of ungraded garnet suitable for sandpapers is about \$93 per ton f.o.b. New York. Prices of graded garnet grain range up to \$160 per ton. Superfine powders in the 5 to 10 micron size for lens grinding sell at about \$200 per ton.

Silica in many forms is used for abrasive purposes, including quartz and quartzite, sandstone, flint, amorphous silica, tripoli, diatomite, and rotten-

stone. Its particular abrasive use depends mainly on sharpness of the grains.

Crushed and graded **quartz** is used for abrasive backing of the cheapest of all abrasive-coated papers, *flint* sandpapers, which are used extensively for working with soft woods. Garnet and quartz papers may be used for the same type of work but generally the quartz, or flint-papers, are used for soft woods and the garnet papers for hard woods. True flint papers are used extensively in Europe for both types of work, as true flint has better cutting qualities and longer life than ordinary quartz. Powdered quartz and silt are sometimes used for scouring compounds and for harsh metal polishes.

Silica sand from sandstone and beach sands is used extensively for sand blasting, metal spraying, initial grinding or surfacing of plate glass, and cutting with gang saws on stone. Although grains are usually spherical, they may be sharp if they were not moved far during the stage of deposition in the original sediments. Natural silica sands are formed by the breakdown of sandstone, quartz, or quartzite and occur as beaches along lakes and oceans. They consist essentially of quartz grains with varying quantities of impurities. There is no production of abrasive sand in Canada and requirements are obtained from the United States.

In sand-blasting or metal-spraying operations the sand must be absolutely dry and free from dust. It can be used over and over again until the grains become too fine. The following size ranges for sand blasting have been outlined: sand No. 1, 20 to 35 mesh; No. 2, 10 to 28 mesh; No. 3, 6 to 10 mesh; No. 4, 4 to 8 mesh. No. 1 is used for light work where comparatively smooth finish is desired: for finishing brass, making automobile castings, frosting glass, and removing paint. No. 2 is used for similar work of a heavier nature. Sands No. 3 and 4 are used for cleaning heavy cast iron and steel work.

Apparently no Canadian sand or sandstone has been used for sand blasting or for coating abrasive papers. In some trials it was found that after processing the material was too fine-grained or fractured too easily in use. The Lorrain quartzite which is quarried by Canadian Silica Corp. Ltd. on Manitoulin Island for the manufacture of artificial abrasives could be a source of sand for this purpose.

Canadian Consumption of Silica Sand

About 100,000 tons of silica sand valued roughly at \$600,000 are consumed annually in Canada in the manufacture of artificial abrasives. For the manufacture of silicon carbide, specifications vary widely from company to company, but in general the material would be between 35 and 60 mesh and contain a minimum of 98.5 pct SiO_2 , with a maxima of 0.5 pct aluminum oxide, 0.035 pct ferric oxide, and 0.2 calcium and magnesium oxides combined. Grain shape is not important in silica to be used for the manufacture of silicon carbide.

Silica sand from a sandstone deposit at St. Canut, in Two Mountains County, Que., is quarried by the Canadian Carborundum Co. Ltd. for making silicon carbide in the Shawinigan Falls plant. A Potsdam sandstone is quarried near Joyceville north of Kingston, Ont., by Kingston Silica Mines Ltd. for use in steel foundries and for manufacturing artificial abrasives. Lorrain quartzite, quarried by two companies, one on Manitoulin Island and one nearby on the mainland, is used in the manufacture of silicon and ferro-silicon. These are the current Canadian

sources of silica. Most of the silica sand of high quality is imported and, including sand for glass manufacturers, amounts to approximately 700,000 tons annually.

Grindstone production in Canada in recent years has been negligible. Material suitable for grindstones, oilstones, millstones, chaser stones, and other types of sharpening stones occurs in sandstone beds of Nova Scotia, New Brunswick, and the coast of British Columbia. Many years ago output from quarries operated in these provinces was considerable, but competition from artificial abrasives has all but eliminated current demand.

Sandstone suitable for grinding or sharpening purposes must possess uniform hardness and a sharp and even grain and must be free from clay or other impurities. The bond or cement which holds the sand particles together has an important bearing on the quality of the stone. Cements usually consist of limonite, calcite, clay, and quartz and may occur individually as the sole bond or be mixed in varying proportions. Stones having too much clay bond absorb water readily and crumble away. The size of the grit determines the ultimate use of a sandstone for grinding purposes, since the coarser the grit the faster and rougher the cutting.

The only Canadian producer of grindstones, Read Stone Co. Ltd. of Sackville, N. B., ships small quantities of grindstones each year. Production valued at \$10,000 was reported in 1950. The company obtains its stone from quarries near Stonehaven. The Bay of Chaleur Grindstone Co. of Clifton, N. B., reported small production of stone up to 1950 but in recent years has not operated its quarry situated on the Bay of Chaleur near Grand Anse.

Statistics on the imports of natural abrasive stones into Canada from the United States are difficult to obtain, as they are lumped with data for stones made of artificial abrasives. U. S. export figures show that Canada, in 1952, imported grindstones valued at \$27,376 and whetstones, scythestones, sticks, and other small sharpening stones valued at \$21,798.

Pulpstones of natural sandstone used in the grinders of pulp mills have been almost displaced by artificial abrasive in the form of built-up segmental pulpstones of bonded silicon carbide grit. Pulpstones were made from sandstones having a similar texture to those used for grindstones and the same quarry might furnish both types of stones. However, a sandstone bed from which pulpstones can be made must have a thickness of at least 3 ft if even the smallest pulpstones are to be obtained.

The life of a natural pulpstone might be from 3 to 20 months, whereas that of the segmental silicon carbide stones might be from 4 to 7 years. Natural pulpstones have not been produced in Canada for many years, but they have been produced in Northumberland and Westmoreland Counties in New Brunswick and in Gabriola and Newcastle Islands off the east coast of Vancouver Island, B. C. About 800 artificial pulpstones are in use in Canadian pulp and paper mills and about 300 are in stock at the various mills. Most of these have been made by Norton Co. of Canada Ltd., Hamilton, Ont., which also supplies some for export. Artificial pulpstones supplied by Canadian Carborundum Co. Ltd. to the pulp and paper industry in Canada are made in its United States plant and imported into Canada.

Flint is an extremely hard chalcidonic variety of silica (SiO_2), light to dark gray in color, with a prominent conchoidal fracture. Flint pebbles have

long been used for grinding ceramic materials and nonmetallic minerals where iron contamination from the usual steel grinding balls or liners would prove detrimental. Danish flint pebbles ranging from 1 to nearly 8 in. are found on the shores of Greenland and marketed throughout Europe and America. Domestic natural flint pebbles, quartz, and quartzite are often substituted for *true flint pebbles*.

Grinding pebbles in minor quantities are produced in Alberta, where W. May ships a few carloads each year from deposits near Elkwater Lake to several Canadian mining companies. Sometimes tube mill liners, when very low iron content of the product is necessary, are also made of blocks or bricks of either natural or artificially prepared materials free of iron.

Certain silicates are used for abrasive purposes, particularly glassy volcanic rocks such as pumice and volcanic dust, or pumicite. **Pumice**, a silicate of aluminum, occurs as lump or gravel in the vicinity of volcanoes and is usually white or light gray in color. Its cutting or abrasive quality is due mainly to thin partitions of glass between the walls of the cells. Lump pumice varies in composition and contains impurities, such as feldspar and hornblende, which lessen its value as an abrasive because they scratch articles being polished. A good pumice contains 65 to 75 pct silica, 12 to 15 pct alumina, less than 3 pct combined alkalis (sodium and potassium oxides), under 3 pct calcium and magnesium oxide, less than 3 pct iron oxide, and small amounts of other oxides.

Pumicite, sometimes called volcanic dust or ground pumice, is similar to pumice in composition and has similar applications. Pumicite is a natural glass or silicate thrown into the air during volcanic eruption and carried in the air to settle ultimately in beds that may be hundreds of miles from its original source. Of white to grayish color, it occurs as a finely divided powder composed of small, sharp, angular fragments of volcanic glass. Many of these fragments are striated, which helps to distinguish pumicite under the microscope from other forms of silica or silicates.

The most important use for pumicite is in scouring compounds and cleansers. It is made into hand soaps, is sometimes employed as a carrier for insecticides, and is used increasingly as an extender in concrete. Pumice aggregate is imported into British Columbia from nearby Oregon and Washington for making lightweight building blocks at several plants in and near Vancouver.

Volcanic dust or pumicite occurs in many localities in central and western Canada. Extensive beds of volcanic dust occur near Waldeck about 11 miles northeast of Swift Current in Saskatchewan, the deposit consisting of loosely compacted, finely divided material which is generally light buff in color but sometimes nearly white. A pure white pumicite occurs in the Deadman River region about 25 miles north of Savona in British Columbia. Between tuff beds varying in thickness from 10 to 30 ft, horizontal beds of pure white ash 8 to 12 ft thick occur. Here again, transportation difficulties have hindered the development of these deposits. Several other occurrences in Saskatchewan and British Columbia are on record.

Extensive pumicite beds occur in Nebraska and Kansas in the United States. The majority of the beds are wind-blown deposits 6 to 10 ft thick, covered with overburden. Imports of pumice and pumicite into Canada, mainly from the United States,

grouped together with lava and calcareous tufa, were valued at \$110,369 in 1952 compared with \$128,957 in 1951. The pumice aggregate imported into British Columbia from Oregon and Washington is laid down at Vancouver from \$6 to \$9 a short ton. Prices for pumice and pumicite vary widely and are dependent upon availability of supply, the use to which the material is put, and the quantities required. Recent quotations on pumicite were from 3¢ to 5¢ per lb, and for good quality pumice 6¢ to 8¢ per lb, f.o.b. New York or Chicago.

Diatomite consists of microscopic siliceous skeleton remains of diatoms, a form of algae. It has the appearance of chalk when dry but is extremely light in weight. When pure it contains up to 96 pct silica in the form of the diatom skeletons.

Diatomite is used for filtration, coating ammonium nitrate prills, insulating against heat, cold, and sound, and admixing concrete. It has a minor use as an abrasive in paste and liquid metal polishes, and in dental powders and pastes, where grit, with consequent scratching, can not be tolerated.

There are more than 300 known occurrences of diatomite in Canada, but these are mainly of the bog type and the processed material would not be suitable for the major uses. There are large dry compact beds of diatomite near Quesnel, B. C., but transportation difficulties have hindered their development.

Known to the trade as soft silicas, tripoli, microcrystalline silica, and rottenstone are fine-grained and porous. There is no production of these materials in Canada and they are not listed separately in import figures but are included in miscellaneous imports.

Tripoli is a form of silica closely resembling diatomite but of entirely different origin. It was first quarried in Missouri and because of its close resemblance to material occurring at Tripoli, North Africa, it was called tripoli although the African product is true diatomite. Under high magnification the grains in tripoli have a mostly globular or spongy appearance in contrast to the striated, sharp, glass-like fragments in volcanic dust or the absence of all diatom structure in diatomite. It is used in the form of grease bricks or compositions for buffing and polishing metals and plated products. It is also used in the manufacture of some scouring and cleaning powders and soaps.

Microcrystalline silica appears to be a decomposition of chert (a form of flint) and generally occurs mixed with unaltered chert. It is usually pure white but may be stained by iron oxides to cream yellow or rose. Microcrystalline silica comes mainly from southwestern Illinois, Missouri, and Tennessee and like tripoli is used in buffing and polishing compounds. Both tripoli and microcrystalline silica are used in paint as fillers, in insecticides as carriers, and in the manufacture of rubber.

Rottenstone is a residual product derived from weathering and decaying of a siliceous argillaceous limestone where the calcium carbonate and other impurities have been leached out to leave a siliceous skeleton. It occurs as a soft, friable, fine-textured earthy mass usually greyish in color. Produced at Antes Forte, Lycoming County, Pa., it is used as a base for automobile and furniture polishes.

The total production value of these three substances in the United States amounts to \$200,000 annually (about 12,000 tons).

Ground feldspar, chalk, china clay, and bath brick are used in minor amounts as ingredients in scouring and cleansing compounds and in fine polishing powders. They are also mild abrasives for hand polishing plated ware. Chalk (calcium carbonate) is a soft, compact, fine-grained white limestone composed of the calcareous remains of small marine shells. Bath brick is made from a very fine-grained quartzose clay found in England.

Summary

The list of natural abrasives might include any mineral capable of abrasive action. Natural abrasives occur throughout the world, and frequently local deposits of abrasive material render it convenient to use that material for a purpose to which some other type of abrasive is more suited. Economics often determine which abrasive is to be used for a particular job, but there are some applications to which only a particular abrasive may be applied.

References

- V. L. Eardley-Wilmot: Abrasives, Pt. I. Siliceous Abrasives. Mines Branch, Dept. of Mines, Ottawa, Pub. No. 673 (1927).
V. L. Eardley-Wilmot: Abrasives, Pt. II, Corundum, Emery, and Diamond. Mines Branch, Dept. of Mines, Ottawa, Pub. No. 675 (1927).
V. L. Eardley-Wilmot: Abrasives, Pt. III, Garnet. Mines Branch, Dept. of Mines, Ottawa, Pub. No. 677 (1927).
V. L. Eardley-Wilmot: Artificial Abrasives and Products. Mines Branch, Dept. of Mines, Ottawa, Pub. No. 699 (1930).
Minerals Yearbook, U.S. Bureau of Mines 1948, to date.
R. B. Ladoo: *Non-Metallie Minerals: Occurrence, Preparation, and Utilization*. McGraw-Hill Book Co., New York.
Industrial Minerals and Rocks: Seeley W. Mudd Series, AIME, New York, 1949.
Mines Branch Publications of the Department of Mines and Technical Surveys, Ottawa.
John S. Crandall: Production and Marketing of Garnet Abrasive Sands. *Trans. AIME* (May 1950) 187.

Evaluating the Performance of a Cleaning Unit

by J. Visman

A simplified method of assessing the characteristics of a cleaning unit, including washability curves, yield figures, ash error, separating gravities, and error curve.

FOR more than 25 years evaluations of coal cleaning units have appeared in many publications, and during this time considerable progress has been made in developing the theory and techniques of calculating washery results. A variety of characteristics have been defined over the years, many receiving general recognition during the first post-war Coal Preparation Conference in Paris in 1950. Coal preparation has become a science, and the approach to preparation problems is being revolutionized. Formerly, for example, if a coal operator wanted to know the performance of a given cleaning unit for a particular grade of his run-of-mine, he either shipped a carload to the manufacturer for a test run or relied on a report of a test carried out on a coal similar to the one he intended to clean. In modern practice the expensive, time-consuming test work generally can be avoided if the washability curves of the coal in question and the error curve of the cleaner are known. Normally a guarantee can be given on the strength of this information. General acceptance of modern standards has thus reduced the need for pilot-scale models of existing types of coal cleaners.

Needless to say, the method requires exhaustive and accurate information on the cleaning unit and on all the additional circumstances affecting its results, information that ultimately can be secured only from actual tests made in the laboratory or in the washery.

It is not the purpose of the present discussion to compare the merits of various characteristics, but to describe the general method of calculation, including a method of obtaining data with a minimum of laboratory work.

All data presented here were derived from tests made at the plant with portable field equipment, using small quantities of varsol, carbon tetrachloride, and bromoform. It will be explained later that the use of standard fractional ash contents designated *normalized ash contents* aids considerably in reducing the routine testing of coal cleaners. Like any other statistical procedure, this method has limitations, and it is not recommended for any work in connection with guarantees. Even a varying commodity such as coal, however, will follow the law of large numbers, which is the basic law of statistics, thus allowing simplification of test work without appreciable loss of accuracy.

The characteristics needed for evaluating cleaner performance are normally derived from a float-sink analysis of samples of the clean coal and the refuse, followed by ash determinations of the various fractions. Usually a sample of feed is also collected to find its ash content and to make a single specific gravity cut, both in connection with determination

J. VISMAN is Preparation Engineer, Office of the Fuels Div., Calgary, Alberta, Dept. of Mines and Technical Surveys, Ottawa, Ont., Canada.

Discussion on this paper, TP 3898F, may be sent (2 copies) to AIME before Dec. 30, 1954. Manuscript, March 8, 1954. Joint Session CIMM and Coal Div., AIME, February 1954.

of yield. This test work is time-consuming, especially for larger sizes of coal, and therefore is seldom done at the plant. Even the manufacturers of coal-cleaning equipment sometimes dispense with a float-sink test, basing their guarantees on an ash reduction figure and the yield. The last-named figures are generally considered insufficient information, as they change according to coal composition and density of separation. No single characteristic, in fact, adequately describes the efficiency of a coal cleaner. The one that comes closest is the *error curve*, with its derivatives, the *separating gravity*, the *probable error*, and the *imperfection*, but it lacks the directness and simplicity of other characteristics. A complete set of characteristics is needed for an adequate picture of the separation. Such a list might include the following: actual yield; theoretical yield; yield error; efficiency (organic); ash error; separating gravity, at actual yield; separating gravity, at actual ash content; separating gravity, from the error curve; probable error of separation; and imperfection.

The calculations involved are presented in a standardized form by means of a schedule*, Table I,

* The schedule is a revised form of a table originally introduced at the Staatsmijnen, Holland.

and two graphs, Figs. 1 and 2, showing the washability curves and the error curve, respectively.

Normally test work needed for evaluating the performance of a cleaner includes a float-sink test from 5 to 8 gravity cuts for the clean coal and the refuse. The cuts may range from 1.25 to 2.5 sp gr, including one separate cut of the feed sample, at 1.60 sp gr.

After being dried and weighed, all the gravity fractions are analyzed for ash. The observational data, including 14 to 20 weight percentages and the same number of ash figures, are now entered in columns A, B, C, and D of the table.

The *actual yield*, Y , is found from the formula

$$Y = 100 \frac{r - f}{r - c} \text{ pct} \quad [1]$$

Generally, the average of two estimates of the yield is calculated, one derived from the ash contents and one from the float percentage at 1.60 sp gr.**

** There is no objection to using a density cut different from 1.60 sp gr, provided it is the same for each of the products concerned.

Thus, r = ash of total refuse, f = ash of total feed, and c = ash of clean coal.

When the formula is used for the second estimate of the yield, r = floats of refuse at 1.60 sp gr, wt pct; f = floats of feed at 1.60 sp gr, wt pct; and c = floats of clean coal at 1.60 sp gr, wt pct. The yield figure is marked down in the outlined part at the foot of column E, and its complement, $100 - Y$, in column F. The table is then filled as indicated in the headings of the columns.

The washability curves, Fig. 1, are found from the table, columns L, O, and S being used in conjunction with the cumulative weight percentages given in column M. The error curve, No. 1 in Fig. 2, is found from column T. It signifies the sharpness of separation and provides the estimates of the separating gravity, d ; the probable error, r , at separating gravity, d ; and the imperfection, I .

The cleaning characteristics are then derived from the curves and entered in the righthand top corner of the table. It is well to check figures found from the curves with the data on the table, by interpolation.

The *theoretical yield* is found from the washability

curve of the floats, i.e., curve No. 1 in Fig. 1. It is the yield value that corresponds with the actual ash content of the clean coal. The figure is also calculated from columns M and O, by interpolation.

The *yield error* is the difference between *actual yield* and *theoretical yield*.

$$\text{The organic efficiency} = 100 \frac{\text{actual yield}}{\text{theoretical yield}}$$

The *ash error* is defined as the difference between actual ash content of the clean coal and the ash content that corresponds with the actual yield, on the washability curve of the floats, see curve No. 1, Fig. 1. The latter ash content is called the *theoretical ash content*. This figure is also calculated from columns M and O, by interpolation.

Separating gravity at actual yield is the specific gravity found from the washability curve representing the specific gravity distribution, see curve No. 4, Fig. 1. It is the specific gravity that corresponds with the actual yield; it is also calculated from column M, by interpolation.

Separating gravity at actual ash is found from the same curve. It is the specific gravity of separation that corresponds with the actual ash content and therefore corresponds with the theoretical yield found from curve No. 1 of Fig. 1. The figure is also found from column O, by interpolation.

The separating gravity, d , from the error curve, corresponds with the specific gravity of those particles in the feed of which 50 pct goes with the clean coal during separation and the other 50 pct with the refuse. In curves 1 and 2, Fig. 2, this separating gravity therefore corresponds with a refuse percentage of 50.

The probable error of separation, r , from the error curve, is the specific gravity interval that corresponds with the interval of 25 to 75 in refuse percentage, divided by 2, see curves 1 and 2 of Fig. 2. The refuse percentages per specific gravity interval are also called *Tromp numbers*, or *distribution percentages*.

The imperfection, I , is found from the formula

$$I = \frac{r}{d - t} \quad [2]$$

where r = probable error of separation, from the error curve; d = separating gravity, from the error curve; and t = density of the medium.

There are a number of other characteristics for expressing the performance of a cleaner, but they will not be defined here. All can be derived from the data presented in the schedule for the calculation of washery results, Table I.

The testing method outlined above is laborious, however satisfactory the information, and simplification of laboratory work would render it more suitable for plant practice. By using the procedure described below it is possible to obtain a very close approximation of cleaner performance from the usual number of float-sink tests without the necessity of conducting fractional ash determinations.

The relationship between the ash content, the volatile matter content, and the specific gravity of coal has been studied by several investigators.¹⁻⁵ It appears that the fractional ash contents and specific gravity of the individual coal are closely related. As specific gravity determination is more simple and less time-consuming than ash determination, various methods have been devised to determine the ash content of a coal from its specific gravity.

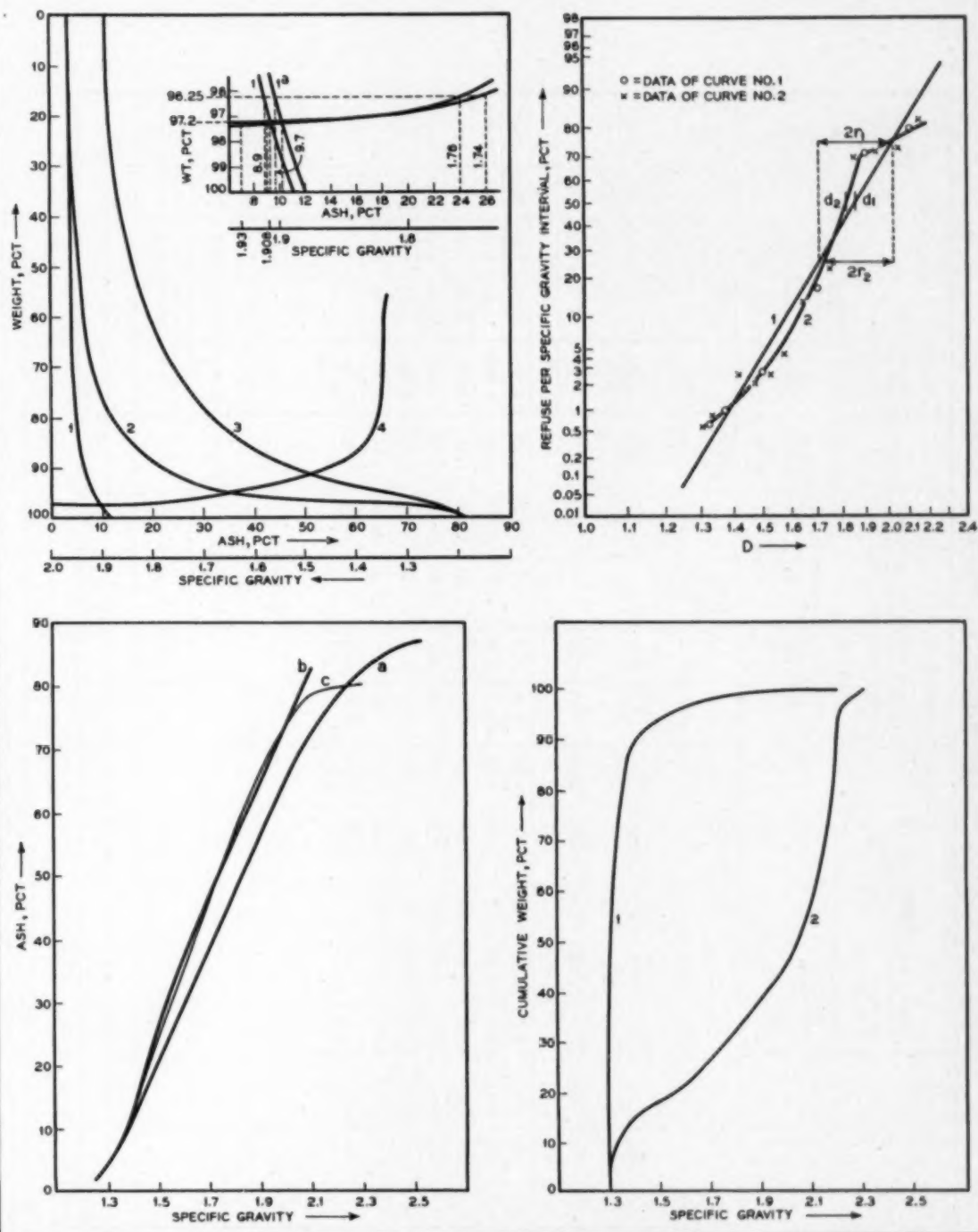


Fig. 1 (upper left)—Curve 1, washability curve of the floats. Curve 2, washability curve of the feed. Curve 3, washability curve of the sinks. Curve 4, specific gravity distribution. Curve 1a (see inset), washability curve of floats for normalized ash contents. Fig. 2 (upper right)—Error curves. Fig. 3 (lower left)—Normalized ash contents. Curve a, average curve of bituminous coals. Curve b, average curve of subbituminous coals. Curve c, average curve of one individual subbituminous coal. Fig. 4 (lower right)—Cumulative weight-density curves: 1, clean coal and 2, refuse.

One possible way would be to find the specific gravity of a sample coal by weighing it in air and then weighing it submerged in water. The corresponding ash content can then be found from the ash-density curve† of that coal. The accuracy of this

† This is a short name for the curve representing the relationship between the ash content and specific gravity of a coal.

method, however, is low, one of the reasons being that the ash figure is based on only one observation of the specific gravity.

[illegible]

FOOTNOTES.—¹ The feed figures are used for the computation of the yield, together with those of the clean coal and refuse.
² The separating gravities at actual yield and at actual ash are found from stability curves Nos. 1 and 4.
³ The probable error of separation is one-half of the specific gravity interval lying between Tromp numbers 23 and 75 on the error curve.
⁴ The calculation of the error curve (data given in column T) requires the data in columns A, C, E, F, and H only.

Table II. Schedule for Calculation of Washery Results

General information				Test data				Test results												
Mine: Subliminuous B Washer: A14-250-S0.7 Size of feed: 1 x 2 in. Feed, tons per hr.: 5 Washing medium: Air Density: $\epsilon = 0$ Viscosity: $\eta =$				Duration of test: 40-3.10 a.m. Weight of Sample: 255, clean 50, refuse 10. Number of increments: 60 Ash content: 11.2 % Floats at: 1.00 spec. gravity: 4.5 % Yield of clean coal, computed from: 98.1 % (1) the ash contents (2) the floats at: 1.60 sp. gr: 96.4 % Mean: 96.25%				Theoretical yield: 97.2 % Yield error: 1.0 % Organic efficiency: 99.0 % Ash error: 0.5 % Separating gravity: (1) at the actual yield: 1.74 (2) at the actual ash content: 1.83 (3) from error curve: 1.83 Probable error of separation: $d = 1.63$ $r = 0.14$ Imperfection $I = \frac{r}{d} = 0.03$												
SPECIFIC GRAVITY INTERVAL	CLEAN COAL				REFUSE				COMPUTATION OF FEED				COMPUTATION OF WASHABILITY CURVES				Error curve ¹			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	Weight %	Ash %	Weight %	Ash %	Weight %	Weight of refuse in % of feed	Ash in refuse in % of feed	Ash in refuse in % of feed	Ash in clean coal in % of feed	Weight of clean coal + refuse in % of feed	Ash in feed (corrected for No. 1)	Ash in feed (corrected for No. 1)	Cumulative weight of feed	Cumulative ash in % of feed	Cumulative ash in % of feed (washability No. 1)	Cumulative ash in % of feed (washability No. 1)	Cumulative ash in % of feed (washability No. 1)	Cumulative ash in % of feed (washability No. 1)	Cumulative ash in % of feed (washability No. 1)	Cumulative ash in % of feed (washability No. 1)
- 1.32	55.0	5.6	8.7	5.6	55.825	0.325	3.125	0.018	3.144	56.151	5.599	- 1.32	56.151	3.144	5.599	43.649	8.935	20.4	0.6	
1.32 - 1.35	16.4	8.0	3.2	8.0	15.765	0.120	1.262	0.040	1.272	15.905	7.997	- 1.35	72.056	4.416	6.128	27.944	7.663	27.4	0.8	
1.35 - 1.40	15.4	13.2	3.7	13.2	14.534	0.139	1.918	0.018	1.936	14.673	13.194	- 1.40	86.729	6.352	7.324	13.271	5.727	43.1	1.0	
1.40 - 1.45	2.7	18.6	1.8	18.6	2.599	0.008	0.468	0.012	0.500	2.667	18.747	- 1.45	89.396	6.892	7.665	10.604	5.227	49.3	2.5	
1.45 - 1.50	2.0	24.4	1.1	24.4	1.925	0.041	0.470	0.010	0.460	1.996	24.415	- 1.50	91.382	7.332	8.025	9.638	4.747	55.0	2.1	
1.50 - 1.55	1.5	30.4	1.0	30.4	1.444	0.038	0.438	0.012	0.460	1.482	30.304	- 1.55	92.644	7.782	8.362	7.156	4.297	60.0	2.6	
1.55 - 1.60	1.3	36.0	1.5	36.0	1.251	0.056	0.400	0.020	0.470	1.377	35.900	- 1.60	94.151	8.252	8.765	5.649	3.827	65.4	4.3	
1.60 - 1.70	1.5	46.8	5.7	46.8	1.444	0.214	0.576	0.100	0.776	1.656	46.803	- 1.70	95.609	9.028	9.423	4.191	3.051	72.8	12.9	
1.70 - 1.80	0.8	57.2	6.1	57.2	0.770	0.229	0.440	0.131	0.571	0.909	57.157	- 1.80	96.908	9.599	9.916	3.192	2.489	77.7	22.9	
1.80 - 1.90	0.1	66.4	5.9	66.4	0.096	0.221	0.064	0.146	0.210	0.317	66.246	- 1.90	97.125	9.809	10.009	2.875	2.270	79.0	69.7	
1.90 - 2.00	0.1	74.0	6.5	74.0	0.096	0.244	0.071	0.180	0.251	0.340	73.824	- 2.00	97.465	10.060	10.392	2.535	2.019	79.6	71.8	
2.00 - 2.10	0.2	78.6	14.1	78.6	0.162	0.528	0.151	0.416	0.567	0.720	78.750	- 2.10	98.165	10.627	10.823	1.815	1.462	80.0	73.3	
2.10 - 2.20	0.3	80.0	35.9	80.0	0.259	1.346	0.231	1.076	1.307	1.635	79.938	- 2.20	99.820	11.934	11.965	0.180	0.180	80.6	82.3	
2.20 - 2.30	-	-	44.8	80.6	-	0.160	-	C, 145	0.145	0.160	80.596	- 2.30	100.000	12.079	12.079	-	-	-	-	
	100.0	10.17	100.0	61.28	95.250	3.750	9.755	2.294	12.079											

FOOTNOTES—¹ The feed figures are used for the computation of the yield, together with those of the clean coal and refuse.
² The separating gravities at actual yield and at actual ash are found from washability curves Nos. 1 and 4.
³ The probable error of separation is one-half of the specific gravity interval lying between Trapez numbers 25 and 75 on the error curve.
⁴ The calculation of the error curve (data given in column T) requires the data in columns A, C, E, F, and R only.

If, on the other hand, the estimate is based on a number of specific gravities, as for the cleaning characteristics subsequently to be described, the accuracy can be improved considerably. In many instances, therefore, it is unnecessary to determine the fractional ash contents once the ash-density curve of a coal is known. The ash figures thus found are termed *normalized ash contents*.

Analyses of coal carried out by the Division of Fuels, Ottawa, during the past 35 years provide much information on the ash-density relationship of Canadian coals. The curves presented in Fig. 3 were derived from 90 float-sink tests and a series of pycnometric tests for the fraction above 1.60 sp gr. Curve a represents the average ash-density relationship for bituminous coals. Curve b stands for the subbituminous coals. Sufficient data are not available for a curve of the anthracite coals.

These curves can by no means be regarded as typical for an individual bituminous or subbituminous coal. The normalized ash contents must be determined separately for every case. Comparison of such an individual curve with the average curve will then show the difference between the average and the coal in question and will point to its specific cleaning properties. It will appear that the upper part of any individual ash-density curve may digress appreciably from the average because of the different nature of the impurities. Note, for example, curve c of Fig. 3. Composition of the coal substance, on the other hand, shows a marked resemblance to other coals of the same rank. The lower part of the individual ash-density curve runs generally parallel to the average, the distance between the two being determined by the difference in volatile matter.[†]

[†] Another characteristic of raw coal is that its ash-consist curve is of a binomial frequency curve type. This can be shown by plotting on log-probability paper the free ash content (equals total ash minus inherent ash of lightest fraction) of every specific gravity fraction against the cumulative weight. The resulting curve approximates a straight line, up to around 60 pct ash, where the presence of the impurities becomes predominant. Similar curves have been observed by H. J. de Wijs for the distribution of the metal content in ores.² The binomial character of the curve relating to coal, although of no immediate advantage for the calculation of cleaner performance, reveals another statistical property which, conversely, can be retraced from limited information by statistical inference.

Evaluation of Cleaner Performance

The 1x2-in. subbituminous coal analyzed in Table I by the conventional procedure is here examined by the simplified method of normalized ash contents and the results set forth in Table II. Data for the construction of curve c of Fig. 3 were derived from a series of four float-sink tests and ash analyses. Note that the main portion of the curve closely follows the average curve for subbituminous coals. The top part deviates distinctly because the impurities consist of a light bentonitic shale containing about 16 pct moisture.

The individual float-sink test was made in the customary way, with 7 to 10 gravity cuts. The relative data of Table I will be used as an example, that is, the figures of columns A and C and the yield figure given at the bottom of column E.[‡]

[‡] Computation of the yield, as previously described (see Eq. 1) includes finding the float percent at 1.60 sp gr and the total ash content of the feed, clean coal, and refuse, respectively.

Computation of the cleaning characteristics is started by plotting on a separate graph the specific gravities of the clean coal and the refuse against their cumulative weights, see Fig. 4. The curves are used for finding the distribution of material within the specific gravity intervals. Differences in distribution

are at once apparent when the ash contents of corresponding specific gravity intervals of the clean coal and refuse of Table I are compared. Ash contents of the refuse cuts are generally higher than the corresponding ash contents of the clean coal. It is clear that these ash contents should be the same if the specific gravity intervals were taken very small. A large number of narrow specific gravity intervals can be derived from the curves, Fig. 4, by interpolation. The resulting data are given in Table II, columns A and C. The normalized ash contents corresponding with the middle of each interval are then found from the ash-density curve c of Fig. 3 and filled out in columns B and D of Table II. From here on computation of results is exactly as explained in the previous example and in the table headings.

Comparison of the Standard and Simplified Methods

The two tables, which represent the same separation, can now be compared. The washability curves show certain differences, as expected, but the cleaning characteristics correspond satisfactorily, as shown in Table III.

Table III. Comparison of Data Obtained by Standard and Simplified Methods

Characteristic	Actual Ash Contents, Pct	Normalized Ash Contents, Pct
Theoretical yield	97.2	97.2
Yield error	0.9	1.0
Efficiency	99.0	99.0
Ash error	0.4	0.5
Separating gravity at actual yield	1.76	1.74
Separating gravity at actual ash	1.91	1.93
Separating gravity from error curve	1.86	1.83
Probable error of separation	0.16	0.14
Imperfection	0.09	0.08

The straight line of Fig. 2, curve No. 1, indicates the paucity of data. It shows that a flattering picture of the performance of the cleaner may arise through insufficient information. On the other hand, the method of normalized ash contents, providing more data, defines the shape of the error curve in greater detail. For instance, curve 2 of Fig. 2 is based on 13 points and reveals that in reality the error curve is nonlinear. The shape of the error curve is of particular interest because it aids in detecting certain deficiencies of a cleaner, among others those caused by maladjustment and variations of the separating gravity.⁴⁻⁶

Acknowledgment

Permission to publish this paper has been granted by the Deputy Minister, Dept. of Mines and Technical Surveys, Ottawa, Ont.

References

- ¹ E. S. Grumell and A. C. Dunningham: Distribution of Ash in British Coals. *Colliery Guardian* (1947) 174, p. 39.
- ² M. J. Berteloot: *L'équipement des Charbons. Revue de l'Industrie Minérale* (1946) p. 433.
- ³ H. J. de Wijs: Statistics of Ore Distribution. *Geologie en Mijnbouw* (1951) 13, pp. 365-375; (1952) 14, pp. 12-24.
- ⁴ Belugou and Vitaux: The Control of the Washing of Fine Coals in the Coalfields. Cerchar Conference, Paris 1950, Paper C 1.
- ⁵ J. Visman: The Status of Coal Cleaning in Western Canada. *Bulletin CIMM* (January 1954) pp. 15-23; *Trans. CIMM* (1954) 57, pp. 13-21.
- ⁶ J. Visman: Quality Control Principles in Coal Preparation. *Bulletin, CIMM* (December 1952) pp. 722-727; *Trans. CIMM* (1952) 55, pp. 406-411.

AIME OFFICERS

Leo F. Reinartz, President

Vice Presidents

O. B. J. Fraser Harold Decker A. B. Kinzel
James B. Morrow T. B. Counselman L. E. Elkins
President-Elect, H. DeWitt Smith
Treasurer, G. F. Moulton

AIME STAFF

E. H. Robie, Secretary

J. B. Alford, H. N. Appleton, E. J. Kennedy, Jr., E. O. Kirkendall, Assistant Secretaries. P. J. Apol, Assistant Treasurer
R. E. O'Brien, 808 Newhouse Bldg., Salt Lake City, Field Secretary
C. M. Cooley, Mining Branch Secretary



aime NEWS

E. D. Gardner to Get Jackling Award at Annual Meeting

Who? AIME; What? 1955 Annual Meeting; Where? Conrad Hilton Hotel, Chicago; When? February 14 to 17.

Right now the Chicago Section is hard at work making the physical arrangements for the 1955 edition of the all-Institute get-together. Award committees have been busy since the last annual meeting in New York. One group, for the Daniel C. Jackling Award and Lecture, has named E. D. Gardner as this year's recipient.

The Daniel C. Jackling Award is presented by the Mining, Geology, and Geophysics Div. for "significant contributions to technical progress" in the fields of mining, geology, and geophysics. Reno H. Sales received the award in 1954.

Mr. Gardner is chief mining engineer of the U. S. Bureau of Mines. He was born in West Jordan, Utah, Mar. 31, 1885. He received a B.S. in mining engineering and an E.M. from the University of Utah. Before entering government service in 1911 he worked for Utah Copper Co. Mr. Gardner is the author of 55 Bureau of Mines publications and numerous articles for the technical press. World War II called him to Alaska, North Africa, and Italy, where he contributed his knowledge to the program for increased mineral production.

The Chicago meeting technical program is taking definite shape. Papers are in various stages of execution. As usual at this point some changes can be expected by meeting time.

However, Geology Subdivision, Mining Subdivision, Minerals Beneficiation Div., and Industrial Minerals Div. report that solid progress is being made toward presenting an interesting technical program.

Among the tentative papers listed by IMD are: *Quarry Operation, with Emphasis on Heavy Stripping*, by representatives of National Gypsum Co.; *Raw Material Preparation at the Brandon, Miss., Cement Plant*, by J. C. Holm; *Conservation of Lime and Recovery of Lime in Sulphate Pulp Mills*, by W. Tock; *New Developments in Silica Sands and Abrasives in the Southern Mid-Con-*



E. D. GARDNER

tinient Region, by William E. Ham; *Aggregates for Jet and Rocket Runways*, by Robert Barnett; *High Calcium Limestone in the Appalachian District*, by Byron M. Cooper; *Staurolite—New Industrial Mineral*, by C. H. Evans; *Fullers Earth Industry in the Florida-Georgia District*, by James L. Culver; *Barite as a Filler for Rubber and Asphalt*, by Walter F. Winters; and *General Developments in the Lithium Industry*, by Felix Shay.

The Concentration Committee of the MBD reports that among the assured papers are: *Quantitative Use of X-ray Diffraction for Analysis of Iron Oxides in Gogebic Taconite of Wisconsin*, by R. S. Shoemaker and D. L. Harris; *Depolarizing of Magnetic Pulpes*, by L. G. Hendrickson and M. F. Williams; *Tsumeb Metallurgical Operations*, by J. Ratledge and Jack Ong; *Operations at Silver Bell*, by Norman Weiss; *Flotation of Del Monte Sands*, by Hugh H. Bein; and *Some Physico-Chemical Aspects of Flotation*, by C. C. DeWitt.

Crushing and Grinding Committee reports indicate that among the papers that can be expected to appear on the program are: *Analysis of Variables in Rod Milling, Part II*, by Will Mitchell, Jr., and C. L. Sollenberger; *The Significance of Speed of*

Tumbling Mills on Their Capacity and Power Consumption, by H. T. Hukki; *Rapid Method to Rate Reduction Ratios from Screen Analyses*, by A. Legsdin and F. L. Schenck.

Papers reported as in by the Materials Handling Committee are: *Protective Devices in Mining and Milling*, by J. C. Carlile; and *Handling Difficult Flotation Froths*, by W. H. Reck.

The Mill Design Committee states that papers which have been assured include: *Drafting, Construction Models, and Visual Aids*, by Frank Pettit; *Layout of Grinding Floors*, by Mine & Smelter Supply Co.; *Design of Tubular Conveyor Galleries*, by GECCO; and *Pilot Plant—Purposes and Uses*, by Stephens and MacDonald.

Solids-Fluids Separation Committee announces that papers that have been definitely promised include: *Calculation of Economic Minimum Filter Cake Moisture Content*, by Silverblatt, Emmett, and Dahlstrom; and *Theory and Application of Polyelectrolytes to Flocculation*, by R. A. Ruehrwein.

The MBD will also hold a symposium on *How to Start Up a New Mill*.

Geology Subdivision plans a rather impressive list of papers. To date, such papers as those on geochemistry of Nigerian deposits, Brazilian resources, uranium criteria, uranium genesis, Yukon helicopter exploration, resources of Arizona and Nevada, gravimetric mapping, and many others.

Mining Subdivision planning has proceeded along specific session lines. Four papers are expected for the open pit session on the first meeting day. Stratified mining and support of mine workings will present two papers each. Sessions on the second day will include mining research, a joint session with the Geology Subdivision, and the Jackling Lecture.

Third day papers will cover drilling problems, underground mining problems, block caving, and small mines problems. The last day will feature mine safety and professional development of engineers.

efficiency

Comes "NATURAL" With a
TRAYLOR "S" JAW CRUSHER



NATURE gave the turtle *curved* jaws. They are amazingly powerful for a creature its size. The *curved* jaw plates of a Traylor Crusher apply power for crushing in the same way. They, too, are amazingly efficient. Add to this, a cast steel frame, a 3 bearing toggle system and a patented swing jaw suspension for a good measure of dependability. Look into a Traylor type "S" today, it's just naturally more efficient.

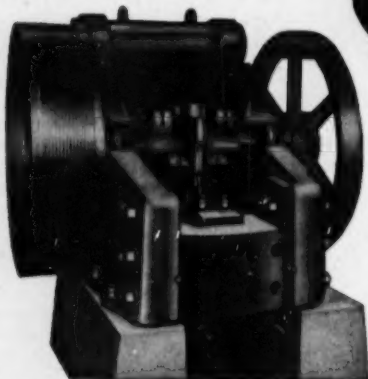


7 sizes with feed openings from 36" x 42" to 60" x 84".

SEND FOR BULLETIN
that gives all the facts

Traylor

LEADS TO GREATER PROFITS



TRAYLOR ENG. & MFG. CO.

694 MILL ST., ALLENTOWN, PA.

Sales Offices: New York • Chicago • San Francisco
Canadian Mfrs: Canadian Vickers, Ltd., Montreal, P.Q.

NATURALLY I'm interested in knowing more about the production efficiency of the Traylor "S" Jaw Crusher.

Name

Company

Address

I'm now crushing tons per hour with a crusher.



Primary Gyrotory Crusher



Rotary Kiln



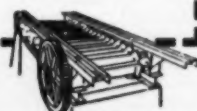
Secondary Gyrotory Crusher



Ball Mills



Jaw Crusher



Apron Feeder

Rocky Mountain Industrial Minerals Conference

Inaugurated at Salt Lake October 28 to 30

The first Rocky Mountain Industrial Minerals Conference is scheduled for the Newhouse Hotel, Salt Lake City, October 28 to 30, with the Utah Section acting as host.

The Industrial Minerals Div. is sponsoring the technical program. It is hoped that the first conference will be the forerunner of an annual gathering. The Utah Section plans to invite other AIME divisions to participate in future affairs.

President-elect H. DeWitt Smith and Mrs. Smith are expected to attend the meeting, along with AIME Secretary Edward H. Robie and Mrs. Robie. One of the principal addresses will be delivered by Honorable J. Bracken Lee, Governor of Utah.

Those responsible for organization of the program were: W. F. Rappold, Vice Chairman, Industrial Minerals Div., Rocky Mountain Region; Roger V. Pierce, Chairman, Utah Section; J. M. Ehrhorn, Vice Chairman, Utah Section; R. E. O'Brien, Field Secretary, AIME; C. R. Fish, Secretary-Treasurer, Utah Section; and Glen Burt, Secretary-Treasurer, Utah Section.



This is one of the industrial centers that conferees at Salt Lake City will visit during planned field trips.

FRIDAY, OCTOBER 29

Technical Session

9:00 am

Co-chairmen—R. C. Talbott, manager, Raw Materials Development, Columbia-Geneva Steel Div., U. S. Steel Corp. and **R. R. Williams, Jr.**, assistant manager, Mining Dept., Colorado Fuel & Iron Corp.

- 1. Industrial Water**
by ElRoy Nelson, vice president, First Security Corp.
- 2. The Role of Industrial Minerals in Utah's Steel Industry**
by John K. Hayes, supervisor, Raw Materials Exploration, Columbia-Geneva Steel Div., U. S. Steel Corp.
- 3. Natural Gas in the Intermountain Area**
by H. F. Hillard, chief engineer, Mountain Fuel Supply Co.
- 4. Chemical Treatment of Ores**
by C. A. Romano, resident manager, Intermountain Chemical Co.

Industrial Minerals Luncheon

12:15 pm

Speaker: Honorable J. Bracken Lee, Governor of Utah

Technical Session

2:00 pm

Co-chairmen—R. R. Williams, Jr., R. C. Talbott

- 1. Titanium**
by C. C. Blalock, mining engineer, Colorado Fuel & Iron Corp.
- 2. Open Pit Phosphate Mining Operations**
by Charles W. Sweetwood, mine superintendent, J. R. Simplot Co.

- 3. The Production of Elemental Phosphorus via the Electrical Furnace Route**
by J. L. Whiteside, plant manager, Monsanto Chemical Co.
- 4. The Economic and Chemical Aspects of Cement Raw Materials**
by John A. Wolfe, chief geologist, Research & Exploration Depts., Ideal Cement Co.
- 5. Barite**
by D. A. Power, manager, Minerals Development Div., Westvaco Mineral Products Div., Food Machinery & Chemical Corp.

SATURDAY, OCTOBER 30

Technical Session

9:00 am

Co-chairmen—J. M. Ehrhorn, director, Industrial Development, U. S. Smelting Refining & Mining Co. and **R. C. Cole**, plant manager, Vitro Uranium Co.

- 1. Uranium in the Colorado Plateau**
by Marvin L. Kay, vice president and general manager, Climax Uranium Co.
- 2. What About Gilsonite?**
by Park L. Morse, American Gilsonite Co.
- 3. Gypsum in Utah**
by W. S. Mole, Certain-teed Products Corp.

Football

2:00 pm

University of Utah vs University of Idaho at University of Utah Stadium, Salt Lake City. Buses will transport those attending game to and from Newhouse Hotel.

Dinner Dance

7:00 pm

Utah Section Annual Fall Cocktail Party and Dinner Dance, Grand Ballroom, Newhouse Hotel.

Marker to John Fritz Unveiled at Pennsylvania Birthplace

A permanent marker to the memory of John Fritz (AIME President 1894) was unveiled at his birthplace in Londonderry Township, Chester County, Pa., under the auspices of the Chester County Historical Society.

The 24x30-in. marker, a gift of Bethlehem Steel Co., is imbedded in a field boulder lying between the sturdy log house in which Mr. Fritz was born and the highway. The house is now covered with clapboard.

Mr. Fritz was employed as general superintendent and chief engineer by the firm, then known as Bethlehem Iron Co., until his retirement at the age of 70 in 1892.

John Fritz Hartshorne, great-grandnephew of John Fritz, briefly reviewed this pioneer's accomplishments and philosophies. It was pointed out that John Fritz probably

exercised the greatest early influence on steelmaking in America.

The Inscription reads:

JOHN FRITZ

August 21, 1822-February 13, 1913 was born and spent his early years here. At age 16 he became an apprentice blacksmith and machinist in Parksburg. In 1854 he was made general superintendent of the CAMBRIA IRON WORKS at Johnstown. In 1860 he was appointed general superintendent and chief engineer of the BETHLEHEM IRON COMPANY. He designed and erected iron-making facilities at Bethlehem which in 1863 were among the largest and most complete in the world. His inventive genius and practical resourcefulness made him one of the world's outstanding figures in the 19th century

history of the iron and steel industry. This marker was erected by the Chester County Historical Society, August 21, 1954.

Invitation Extended By AICE Council

The Council of the American Institute of Consulting Engineers has extended an invitation to past and present officers and directors of the AIME to attend the 1954 annual dinner of the Institute.

It is to be a subscription dinner at \$13.50 per person and will be held October 19 at the Waldorf-Astoria in New York. Herbert Clark Hoover will receive the Award of Merit and the Hoover medal will be presented to Alfred P. Sloan, Jr.

University of Minnesota to Hold Drilling Sessions

The University of Minnesota, inspired by successes in 1952 and 1953, has scheduled another drilling symposium for October 14 to 16. Sessions will begin at 9:00 am on Thursday, October 14 and will conclude at noon October 16. Program will be of the same general nature as the one last year. Registration will be from 8:00 to 9:00 am Thursday.

THURSDAY, OCTOBER 14

Morning

1. Introduction
2. Cements and Grouting
 - A. Characteristics of Cement and use Thereof
 - B. Review of Small Diameter Drilling Hole Cementing
 - C. Grout Hole Drilling in Shafts

Lunch, Center dining room

Afternoon

1. Drilling Techniques
 - A. St. Joseph Lead Techniques
 - B. Diamond Substitutes in Exploration Drilling
 - C. Rotary Exploration Drilling. In Venezuela

FRIDAY, OCTOBER 15

Morning

1. Diamonds for Drilling
 - A. The Current Supply of Industrial Diamonds
 - B. Diamond Orientation

Lunch, Center dining room

1. Soil Testing
 - A. How to Sample
 - B. How to Test
2. Slim Hole Drilling to 5000 ft with 2 3/4 and 4 3/4-in. Holes

Evening

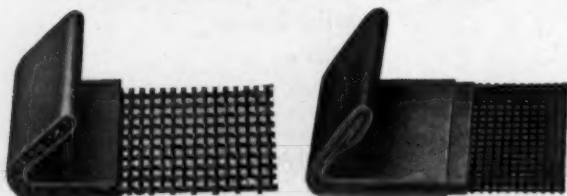
Dinner, Elks Club

SATURDAY, OCTOBER 16

Morning

1. Miscellaneous new devices and practices. A discussion of matters of timely interest.
2. Adjournment

Tyler Screen Sections for All Makes of Screening Machines!



Screen sections of Tyler Woven Wire are fabricated for all makes of vibrating screens in any mesh or metal. They are made up with hook-strip or bent-edge construction to suit the machine on which they are to be used.

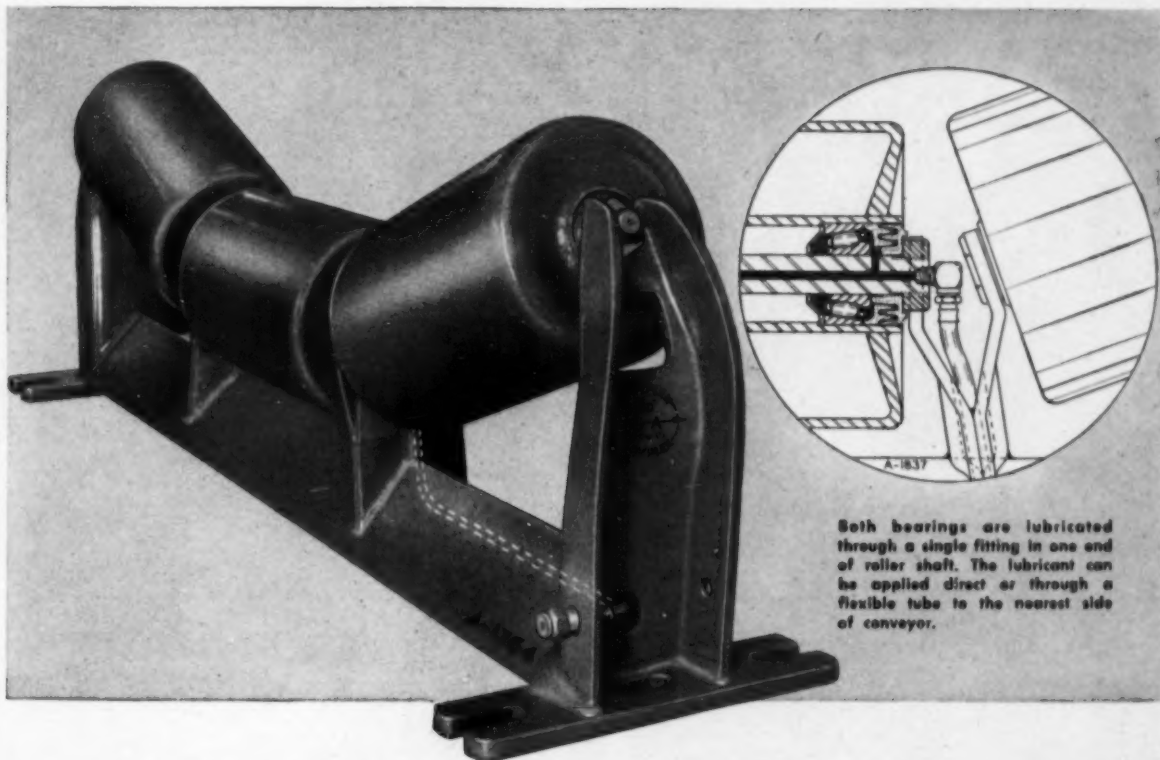
Tyler rugged, accurately-applied hook-strips make possible stretching and maintaining the screens at drum-head tension, which is essential for successful screening and long screen life.

THE W. S. TYLER COMPANY

CLEVELAND 14, OHIO

Manufacturers of Woven Wire Screens and Screening Machinery

Canadian Plant—St. Catharines, Ontario, Canada



Both bearings are lubricated through a single fitting in one end of roller shaft. The lubricant can be applied direct or through a flexible tube to the nearest side of conveyor.

Look What's New in Belt Conveyor Carriers

Spun-end interchangeable rollers . . . ends recessed for close roller spacing . . . 3 shot lubrication . . . all steel frame, reinforced and jig-welded.

"SIMPLEX" Conveyor Belt Carriers, leaders for over 25 years, now include these new features that make them even stronger, better balanced and simpler than before.

SPUN-END, ONE PIECE ROLLERS

Each roller is spun from a single piece of heavy gauge steel tubing with inner bearing-tube welded to spun-ends. Ends are recessed to permit close roller-spacing for maximum belt support.

PARTS INTERCHANGEABLE

Roller assemblies and parts for all three rollers are interchangeable for quicker replacement and minimum stocking.

QUICKER, SAFER LUBRICATION

One shot lubrication for each roller from one or both sides of conveyor. No necessity for reaching under moving belt for center-roll lubrication.

LABYRINTH GREASE SEALS

Die cast non-corrosive labyrinth seals retain lubricant and protect bearings from dirt and moisture.

ALL-STEEL CONSTRUCTION

The one piece all-steel frame is flanged, reinforced and accurately jig-welded for great strength with minimum weight.

CARRIER IS SELF-CLEANING

Inverted angle cross-member and self-cleaning end-brackets prevent material from collecting and fouling rollers.

"SIMPLEX" 220 Series Carriers may be had for all conveyor belts from 18" to 60" wide with 5" or 6" rollers.

"SIMPLEX" Carriers are just one of many types in the complete S-A line. Whether your primary need is maximum years of service or relative low cost, there is an S-A Carrier to meet your requirements exactly.

Write today for Bulletin No. 453 on "SIMPLEX" Carriers or ask to have one of our engineers call — there is no obligation.



STEPHENS-ADAMSON MFG. CO.

37 Ridgeway Avenue, Aurora, Illinois • Los Angeles, Calif. • Belleville, Ontario

Engineering Division

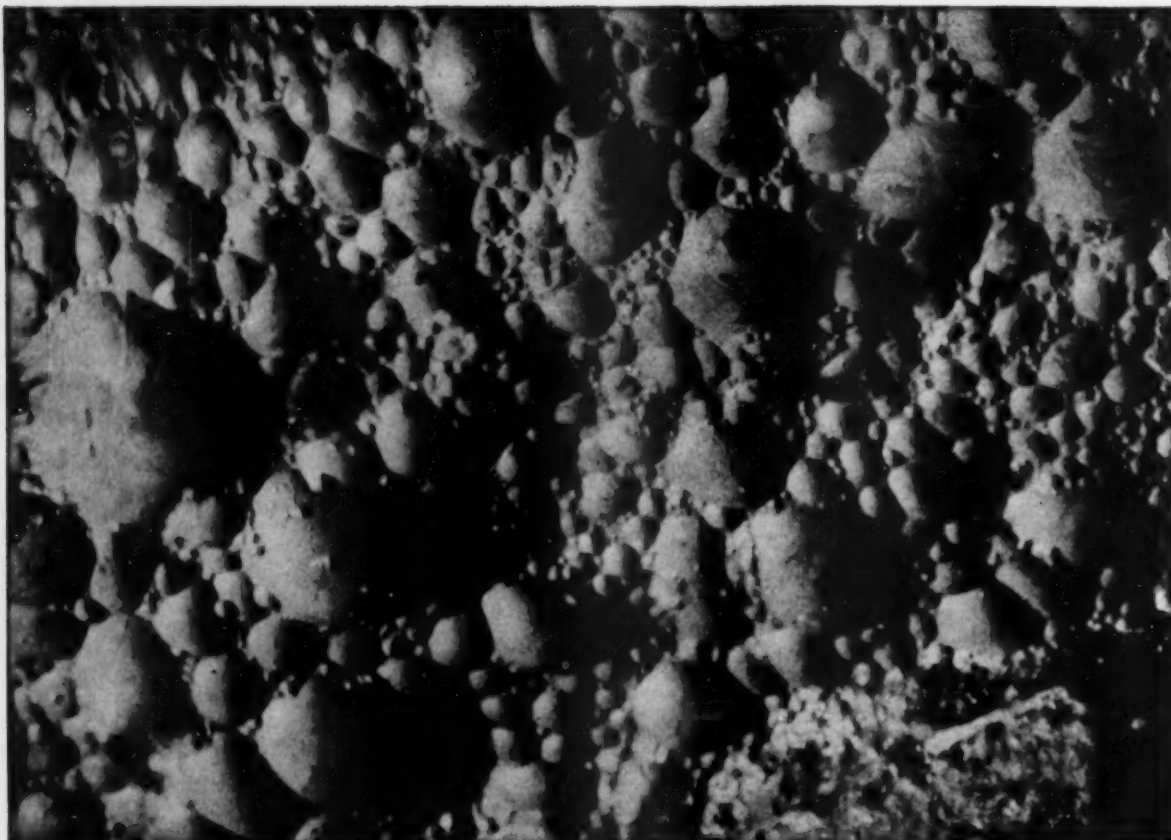
Specialists in the design and manufacture of all types of bulk materials conveying systems.

Standard Products Division

A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.

Sealmaster Division

A complete line of industrial ball bearing units available in both standard and special housings.



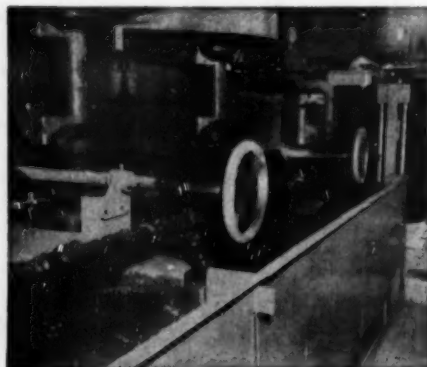
FOR MAXIMUM RECOVERY AT MINIMUM COST

List the characteristics of a good flotation agent and you'll see why Hercules Yarmor® F Pine Oil has remained a standard of quality for more than thirty years. Economy, strong froth with good volume, satisfactory texture, excellent cell-life stability—Yarmor F Pine Oil has them all.

Widely used as a frother for sulfide minerals such as zinc, copper, nickel, iron and lead sulfides, Yarmor F Pine Oil has also shown excellent results in the recovery of gold ores and native metals. This low-cost frother is also ideal for use in the beneficiation of nonsulfide ores such as coal, mica, quartz, graphite, feldspar, phosphate rock, and talc.

Other Hercules' flotation agents include Hercules Rosin Amine D Acetate, a siliceous mineral collector that is particularly suited for the phosphates. For information on these and other Hercules flotation agents, write:

Naval Stores Department
HERCULES POWDER COMPANY
INCORPORATED
955 King Street, Wilmington 99, Delaware



COAL FLOTATION—A growing market for Yarmor is in the recovery of fine anthracite and bituminous from silt.

HERCULES

FLOTATION AGENTS

MMB4-1

Around the Sections

• In an attempt to ascertain the extent of interest in fall meetings, a questionnaire was mailed out to Section Delegates and Section Chairmen of the division by H. R. Gault, Local Section Liaison, **MGGD**. Twenty-four questionnaires were mailed and 13 replies received. Seven of those answering were planning fall field meetings. Six sections—San Francisco, Utah, Black Hills, Columbia, New York, and Lehigh Valley—were interested in joint fall meetings. Schedules given to Mr. Gault for fall field meetings were: **Southeast Section** at Atlanta, Ga., November 12 and 13; **North Carolina Subsection** of the Southeast Section at Durham, N. C., October 22 and 23; **Lehigh Valley Section** at Phillipsburg, N. J., September 10; **Black Hills Section** at Belle Fourche, S. D.; **Nelson Section of the CIM** at Nelson, B. C.; **Minnesota Section** at White Pine, Mich.; **Utah Section** at Salt Lake City; **St. Louis Section** in Southern Illinois. Mr. Gault suggests that the "Institute-wide program of fall meetings should be reviewed with the thought that fall meetings should be on a regional basis rather than on a national divisional basis. Some sections are involved with greater distances between members, making field meetings and joint meetings difficult to operate. There is more or less complete agreement that students would benefit greatly from field meetings. In some instances student participation has been weak. Could it be possible that at times student participation has not been given the personal type of encouragement?"

• Sixteen members and guests attended a recent meeting of the **Adirondack Section** at Whiteface Inn, Lake Placid, N. Y. During the meeting it was stressed that an informal dance is to be held October 8 as part of the social program for the Fall IMD Meeting. Whiteface Inn, incidentally, is in the village of Lake Placid and not on Whiteface Mountain. President Paul Allen appointed Herman Vogel, Robert McClellan, and M. G. Jones as a Nominating Committee for the selection of candidates for the 1955 officers of the section. Adolph LaPrairie, contract sales manager of Canadian Industries Ltd. was the guest speaker. He spoke on the early days of mining in Eastern Canada.

• The **St. Louis Section** held a recent field trip to the Orient mine No. 3 and to Old Ben mine No. 22 preparation plants in Southern Illinois. The Orient mine No. 3 of the Chicago, Wilmington & Franklin Coal Co. at Waltonville was the first stop. This latest development of a major producer boasts the longest slope belt with the highest lift in the industry. Baum type jigs and pneumatic separation handle 1200

tph. Luncheon was at Sesser, Ill., midway point between the Orient and Old Ben. Dinner was at the Franklin County Country Club, West Frankfort, Ill. Golfing facilities at the club were available to AIME members throughout the day.

• The **Lehigh Valley Section** took its annual field trip recently. Forty-eight members of the section visited the Phillipsburg, N. J., plant of the Ingersoll-Rand Co. Tour began with a briefing session at 10:00 am, with coffee and cake served. The tour included the metallurgical dept., manufacturing facilities, forge shop, heat treatment dept. of the Rock

Drill Div., and Compressor Div. Section members were guests of the company at lunch. The Cameron Pump Div. was also inspected. Fall dinner meeting of the section is slated for Hotel Traylor, Allentown, Pa., October 8.

• **Colorado Plateau Section** members were guests of Climax Molybdenum Co., Climax, Colo., on a field trip to the company's mine and mill. William F. Distler and Ed Matson acted as guides to the 16 members of the section who made the trip. The men were shown the Storke level of the mine and later were taken through the mill.

Sprague & Henwood's "ORIENTED" Diamond Bits



Cut Faster Last Longer Cost No More

for
quick
action
call
DIAMOND
4-8507
at
Scranton

Most Economical Diamond Bits Ever Produced

After proving in our own world-wide contract drilling operations that Sprague & Henwood Oriented Diamond Bits (in which each individual diamond is set with its hardest edge or "vector" toward the work) cut much faster and last much longer than when diamonds are set at random, we made them available to other users and THOUSANDS are now cutting costs for diamond-drill operators throughout the mining world.

Specialized equipment and large-scale production enable us to furnish them in a wide variety of types and sizes, with either cast- or powdered-metal matrices, at no advance in price; making them the most economical diamond bits ever produced.

Bulletin 320 illustrates and describes all types and gives complete working data. Write for a free copy and tell us about your diamond drilling requirements. Our experienced executives welcome opportunities to make money-saving suggestions without charge or obligation.

HIGH-SPEED DRILLING MACHINES and Complete Accessory Equipment

Our wide line of high-speed diamond drilling machines meets every requirement for both core drilling and blast-hole drilling at minimum expense. We also manufacture a complete line of improved accessory equipment and carry all commonly used items in stock.

Illustrated bulletins containing complete specifications and working data mailed on request.



CONTRACT DIAMOND DRILLING Any Kind — Anywhere — Any Time

For more than sixty years, Sprague & Henwood, Inc. has been a leader in the field of diamond core drilling by contract. Besides exploratory drilling for ores and other mineral deposits, our service includes foundation test drilling, grout holes and pressure grouting.

Correspondence is invited regarding any diamond drilling job—anywhere. Estimates submitted promptly.



SPRAGUE & HENWOOD, INC. Scranton 2, Pa.

BRANCH OFFICES: NEW YORK • PHILADELPHIA • PITTSBURGH • GRAND JUNCTION, COL. • BUCHANE, NEWFOUNDLAND



Conveyor belt and
storage bins at
loading docks

Crude Sulphur

for Industrial Use

*from
the
properties
of*

Texas Gulf Sulphur Co.

75 East 45th Street • New York 17, N. Y.

Producing Units

- NEWGULF, TEXAS
- MOSS BLUFF, TEXAS
- SPINDLETOP, TEXAS
- WORLAND, WYOMING

Personals

Lloyd M. Scofield, mining geologist and mining engineer, has opened a consulting office at 1014 Fidelity Bldg., Duluth.

Ross D. Leisk, general manager of Sunshine Mining Co. since 1936, has been appointed a vice president and director of the company.

Henry L. Hosmer, formerly geologist, Morococha Div., is now assistant chief geologist of mines, for Cerro de Pasco in La Oroya, Peru. Mr. Hosmer recently returned to Peru after a long vacation during which he did graduate work at the University of Michigan.

H. V. Beasley is in charge of the constructional alloy steels section, Development & Research Div., International Nickel Co. Inc., New York. **Clarence H. Sample** is in charge of the electroplating section. **T. E. Kihlgren** is in charge of Inco nickel alloys development section, and **V. N. Krivobok** is in charge of stainless steels and heat-resistant alloys section. **W. H. Sparr, Jr.**, has been appointed to succeed Mr. Beasley in charge of the technical field section in Pittsburgh.

Roy Dahlstrom, director of the technical dept., Titanium Div., National Lead Co., Sayreville, N. J., has been awarded a gold watch in recognition of 25 years service with the company. Mr. Dahlstrom became a Titanium Pigment Co. fellow at the University of Chicago in 1929, where he received his doctorate, and in 1931 joined the Brooklyn laboratories as research chemist. He was made chief chemist of the Titanium Div. at Sayreville in 1935 and three years later was appointed assistant director of research there. He was advanced to director of research in 1944 and to technical director in 1948.

John R. Parks has been named flotation sales engineer for the Chemical Div. of Armour & Co., Chicago.

Walter Hochschild, president of American Metal Co. Ltd., and **Albert Pratt**, a partner in Paine, Weber, Jackson & Curtis, have been elected to the board of directors of the Copper Range Co. They fill the vacancies caused by the resignations of **Philip F. Beaudin** and **Edward Cunningham**.

Ray H. Rodolf has been appointed general manager, Compressor Div., Le Roi Co., Milwaukee, and **Herschel V. Hiatt**, general manager, Engine Div. Mr. Rodolf, who is now working on the development of large stationary air compressors for use in drilling, was sales manager, Construction & Mining Div. Mr. Hiatt joined Le Roi almost a year ago as director of engineering.



JAMES E. ATKINSON

James E. Atkinson, San Francisco mining engineer and geologist, has been engaged as consultant for the new columbite-tantalite project of the Morabisi Mining Co. Ltd., P. O. Box 183, Georgetown, British Guiana.

Charles H. Burgess, who was district geologist, Kennecott Copper Co., New York, is now with Bear Creek Mining Co., Minneapolis.

Kenneth C. Vincent, ceramics and minerals research dept., Armour Research Foundation, Illinois Institute of Technology, Chicago, now heads the ore dressing section. This newly organized section is concerned with the beneficiation of both nonmetallic and metallic ores. Mr. Vincent was formerly chief metallurgist, Baroid Sales Div., National Lead Co., Malvern, Ark.

John H. Fair is with U. S. Smelting Refining & Mining, Lark, Utah.

Richard N. Hunt, chief geologist and vice president, U. S. Smelting Refining & Mining Co., Salt Lake City, was recently elected to the board of Hecla Mining Co.

George E. Keller is manager, coal evaluation, U. S. Steel Corp., Pittsburgh. He was chemical director, manager, Commercial Testing & Equipment Co., Charleston, W. Va.

Adolph V. Mitterer, Jr., has resigned his position as research engineer with Colorado School of Mines Research Foundation and has accepted a position as junior mine engineer with International Minerals & Chemical Corp., Carlsbad, N. M.

SEND FOR 248-PAGE

WILMOT CHAIN & CONVEYOR Catalog

As Originators of Rivetless Chain,

Wilmot Offers Widest Choice of Chain Sizes and Conveyor Attachments

Catalog 513 is a standard reference on rivetless chain for all applications. Lists the largest available choice of chain sizes and attachments; also every type of part for conveyors and elevators.

Investigate Wilmot DUCTILE IRON Castings—Bulletin 512

WILMOT ENGINEERING CO.

HAZLETON, PA.
Foundry and Shops:
WHITE HAVEN, PA.



JORGE QUINTANA S.

Jorge Quintana S. has returned to Lima, Peru, after visiting copper mines in the West and the Tri-State area. A graduate of the Escuela Nacional de Ingenieros de Lima, Mr. Quintana was particularly interested in underground operations of small mines in the U. S. He is with Cia. Minera Atacocha in Peru.

Stanley D. Michaelson has been named chief engineer of the Western Mining Divisions, Kennecott Copper Corp. Formerly chief engineer, raw materials, for Tennessee Coal, Iron & Railroad Co., Mr. Michaelson will make his headquarters in Salt Lake City.

Alberto F. Thompson, chief of Technical Information Service, Atomic Energy Commission, Washington, D. C., will speak on *The Coming Industrial Applications of Atomic Energy* at the annual joint convention of the New Mexico Mining Assn. and the Southwest International Mining Assn. to be held in Carlsbad, N. M., October 14 to 16.

L. S. Breckon, who spent two years as district geologist for Kennecott Copper Corp. in Australia and the Far East, is now chief of the Land Div. for Bear Creek Mining Co. Mr. Breckon will make his home and headquarters in Salt Lake City.

P. H. Cowdery, mine engineer, formerly with Standard Lime Co., Joliet, P. Q. is now with Chibougamau Explorers, St. Felicien, Que.

H. William Ahrenholz, Jr., associate professor of mining engineering, West Virginia University, Morgantown, has become reaffiliated with The New Jersey Zinc Co. and is in charge of the Ivanhoe mine now under development. His address is Bertha Mineral Div., The New Jersey Zinc Co., Austinville, Va.

Fred J. Hoff is with Climax Molybdenum Co., Climax, Colo.

Rip V. Thompson is superintendent, Metcalf Mining & Milling Co., Delta, Utah.



O. A. GLAESER

W. C. Page, who for reasons of health asked to be relieved of the duties of vice president and general manager, Western Operations, U. S. Smelting Refining & Mining Co., Salt Lake City, has become vice president and consulting manager. **Oscar A. Glaeser** is now vice president and general manager, Western Operations. He was assistant general manager. **Byron E. Grant**, assistant to the vice president and general manager of Western Operations, has been appointed director of labor relations. **Charles C. Hilton**, assistant industrial relations manager, has been named personnel director.

William A. Bowes, geologist, who was with Shenon & Full Consultants, Salt Lake City, is now with the Atomic Energy Commission, Salt Lake Exploration Branch, Div. of Raw Materials, Salt Lake City.

Herbert D. Drechsler is now mill shift foreman, White Pine Copper Co., White Pine, Mich. He was with Armour Chemical Div., Armour & Co., Chicago.



JOSE V. MONFORT

José V. Monfort has just returned from the Philippines where he worked for two years. For the past year he was mill superintendent for Atok-Big Wedge Mining Co. Inc., Baguio. He is now an engineer with Solano County, Fairfield, Calif.

(Continued on page 1032)

Simplify Your Bulk Storage with a

ONE MAN SAUERMAN MACHINE

Sauerman installations provide economical handling of a wide variety of bulk materials, from bauxite to zinc ore . . . at rates ranging from 10' to 800 cu. yds. per hr. Storage areas range from a small bin to ten acres or more.

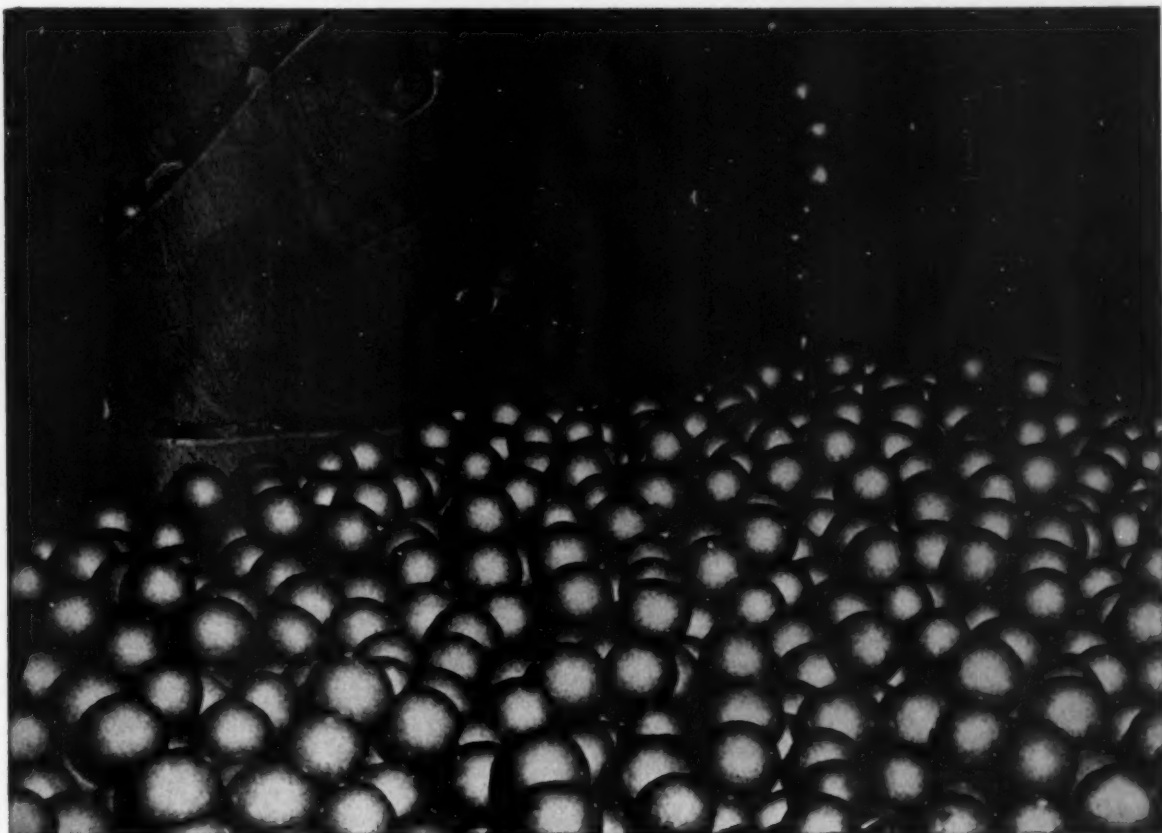
Quick change from stockpiling to reclaiming is accomplished by unclamping and re-attaching the operating cables so as to turn the bucket around when the power is applied. Non-caving or free-flowing materials are handled with equal efficiency. The operator can be located in a safe cab overlooking the work area. Many Sauerman installations are remotely operated through air or hydraulic controls.

Let Sauerman engineers show you how to use your storage area to its fullest extent. Send for Catalog E, Bulk Storage by Power Scraper and 33 Tested Methods For Handling Bulk Materials. Request the following Field Reports:


FR-224 Handling Ore with Drag Scrapers
FR-104 African Storage of Iron Ores

SAUERMAN BROS., Inc.

546 S. CLINTON STREET, CHICAGO 7, ILL.



You Can Cut Costs Here

SHEFFIELD

MOLY-COP
TRADE MARK
COPPER • MOLYBDENUM • ALLOY
GRINDING BALLS

Sheffield copper molybdenum alloy steel grinding balls are manufactured by automatically controlled methods which produce a ball of finer, denser, more uniform structure.

Moly-Cop balls wear evenly and retain their spherical shape longer. They have greater hardness for wear and toughness to resist spalling and chipping. This all adds up to high production rates with less down time, less charging and less power.

Moly-Cop grinding balls can make an important net saving in your grinding cost.

If you have not already proven the value of Moly-Cop balls, get in touch with us before making your next purchase.

SHEFFIELD STEEL

DIVISION

ARMCO STEEL CORPORATION

SHEFFIELD PLANTS: HOUSTON KANSAS CITY TULSA

EXPORT REPRESENTATIVES: ARMCO INTERNATIONAL CORPORATION • Middletown, Ohio



W. PAGE MORRIS

W. Page Morris has been named vice president and assistant general manager of Duval Sulphur & Potash Co., Houston. Succeeding Mr. Morris as resident manager of Duval's mine and refinery at Carlsbad, N. M., is **George E. Atwood**. **Jerry E. Tong**, named to succeed Mr. Atwood as assistant resident manager, will continue as mine superintendent.

E. C. Van Blarcom has accepted an appointment to the Raw Materials Div., AEC, Washington, D. C. For the last four years he has been consulting metallurgist with Singmaster & Breyer, New York.

Ruggles-Coles...



...DOUBLE SHELL DRYERS



...SINGLE SHELL DRYERS



...ROTARY KILNS



...ROTARY COOLERS

Write for Bulletin 16-D-2



YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works
New York • Toronto • Chicago • Milwaukee • Houston • Salt Lake City • San Francisco

Robert H. Aborn, assistant director since 1947 of U. S. Steel's Fundamental Research Laboratory, Kearny, N. J., has been named director. Mr. Aborn has been associated with U. S. Steel for the last 24 years. **Lawrence S. Darken**, **Bernard M. Larsen**, **Donald S. Miller**, and **Reginald L. Rickett**, members of the Kearny staff for many years, have been named assistant directors, respectively, of physical chemistry, metallurgical processes, physics, and physical metallurgy.

P. C. Emrath recently returned to the U. S. from a three-year engagement in development of mineral resources in Formosa with the J. G. White Engineering Corp. of New York. Mr. Emrath, who is now in Lexington, Ky., plans to resume general mining consultation, including work in Southeast Asia.

Kenneth E. Grimm, paleontologist, who joined Johns-Manville Products Corp., Lompoc, Calif., in 1947, is now at the University of Idaho, Moscow. His responsibilities will include courses in paleontology, historical geology, and stratigraphy. Just before resigning his position with Johns-Manville, Mr. Grimm participated in the recovery of a fossil whale from the company's diatomaceous quarries. The fossil is 18 ft long and a mere 17 million years old.

Robert H. Hughes, president of Clinchfield Coal Corp., Dante, Va., has been named to receive the Pi Tau Sigma Richards Memorial Award. The award, which is administered by the Board on Honors of The American Society of Mechanical Engineers, is conferred annually on a mechanical engineer 45 years of age or younger for "outstanding achievement in mechanical engineering within 20 to 25 years after graduation."

John M. Tufts, Jr. of Denver and Arlington, Mass., has been retained by International Mining Corp. to investigate uranium possibilities in the Colorado Plateau and in Wyoming.

J. W. Barnes, formerly assistant superintendent, Stearns-Roger Mfg. Co., Carlsbad, N. M., is with the Processing Div., AEC, Grand Junction, Colo.

George Pelton will have special responsibility for Yuba Mfg. Co.'s new hydraulic dredging program. Yuba has re-entered this field and will build hydraulic dredges from 6 in. up. Mr. Pelton was with the Standard Dredging Co. of New York and Los Angeles for more than 24 years and worked as a consultant on a number of important overseas projects. These include his work as special consultant on Panama Canal construction with the U. S. Engineers and design of a special dredge for the UN, now on harbor construction in Korea.



C. E. BARTLETT

C. E. Bartlett has taken a two-year leave of absence from Combined Metals Reduction Co., Salt Lake City, where he was director of milling, to work with the U. S. Bureau of Mines on technical assistance to the Cuban Government through BANFAIC. His address is c/o American Embassy, Havana.

Grover J. Holt, general manager, Cleveland-Cliffs Iron Co., Ishpeming, Mich., was chosen as Man of the Month by *Cliffs News*. A short biography and a sketch of Mr. Holt appeared in the August issue.

Carlos E. Roggero, who received his B.S. in metallurgy from MIT in June 1954, is shift foreman, Electrothermic Zinc Plant Co., Cerro de Pasco Corp., La Oroya, Peru.

Donald E. Cadwell is with Mining Technical Service, Dow Chemical Co., Pittsburgh. He was with Consolidated Mining & Smelting Co., Kimberley, B. C.



JEAN E. PELLERIN

Jean E. Pellerin, formerly manager of the Société Nord-Africaine du Plomb, Bou Beker, Oujda, French Morocco, has succeeded **Emile Trystram** as manager of the Société des Mines de Zellidja, Oujda. Mr. Trystram, who left in April, had been manager for the past ten years. He is now a member of the board and general manager of Cie des Freins et Signaux Westinghouse in Paris.

Obituaries

Ali De Szepešy Schaurek (Member 1953) died in an automobile accident near Parcoy, Peru, during May 1954. He was a geologist with Northern Peru Mining & Smelting Co., a division of American Smelting & Refining Co., Lima, Peru. He was also a well-known mountain climber. Mr. De Szepešy was on an exploration trip with Werner Bischof, noted photographer, when the chauffeur driving their car missed the road and dropped almost 5000 ft into a canyon. Their bodies were not discovered until days later.

Mr. De Szepešy was born in Szeged, Hungary, in 1923 and studied at the Federal Institute of Technology, Zurich, Switzerland. He first went to Peru with the Swiss Academic Alpine Club of Zurich in 1948 and on his return to Switzerland wrote numerous articles on his experiences there. He returned to Peru in 1950 to work for the Corporación Peruana del Santa and was later chief geologist for the Volcan Mines Co., Yauli Div.

William Harkes (Member 1926) of Coal City, Ill., died Aug. 11, 1954. He was a retired mining engineer. Mr. Harkes was born in England in 1861 and received his early schooling there. After an apprenticeship from 1877 to 1884 in mining engineering, mine management, coking, and refractory manufacturing, he was employed as manager of Wylam Coal Co. in England from 1884 to 1889. The following year Mr. Harkes prospected in the U. S. and in 1891 he became general superintendent and chief engineer, Big 4 Wilmington Coal Co., Illinois. He was later superintendent for Northern Central Coal Co., Missouri, president of Harkes Coal Co., Iowa, and for many years general superintendent of Central Coal & Coke Co., Kansas City.

Keith Roberts (Member 1920) died Mar. 16, 1954. He was a consultant and land surveyor, Menominee, Mich. Mr. Roberts was born in Chicago in 1889 and after receiving his E.M. from Colorado School of Mines in 1915, went to Ontario as an engineer with Tough-Oakes Gold Mines Ltd. After working a short while with Domes Mines Ltd., Ontario, Mr. Roberts worked in a private engineering office in South Porcupine, Ont. During World War I, he was an ensign on submarine duty with the U. S. Navy. He later worked for Hillside Fluorspar Mines, Elizabeth, Ill., and Robert W. Hunt & Co., Chicago. From 1922 to 1923, Mr. Roberts was secretary-treasurer of C. N. Roberts, Chicago, and from 1936 to 1938 he was vice president, Rush-Roberts Engineering Co. He became a manager for Minook Ltd., Rampart, Alaska in 1940. Mr. Roberts remained in Alaska for several years and was at various times

with the Civil Aeronautics Administration, Kodiak, the Alaska Native Service, Juneau, and the Bureau of Land Management Surplus Real Property Div., Juneau.

Frederick LeVerne Serviss (Member 1918) died July 22, 1954. He was professor of geology, Purdue University, Lafayette, Ind. Mr. Serviss was born in Telluride, Colo., in 1895 and received an E.M. in 1920 and an M.S. in 1922 from Colorado School of Mines. He spent two years doing postgraduate work at George Washington University, specializing in geology and economics. Mr. Serviss gained his early experience as a sampler for Primos Chemical Co., Urad, Colo., and as an engineer for Tonopah Placer Co., Breckenridge, Colo., Utah Fuel Co., Salt Lake City, and Colorado Fuel & Iron Co., Trinidad, Colo. He also worked as assistant city engineer and as an engineer with the Water Works in Trinidad, Colo. Mr. Serviss became a member of the Purdue faculty in 1923, assistant professor of geology in 1925, and professor and head of the division in 1934. He was a consultant to Ernest C. Ruebsam, Washington, D. C., Indiana Limestone Corp., Bedford, Ind., and various other industrial concerns.

Harry A. Swem (Member 1920) of Newgulf, Texas, died Aug. 8, 1954 of a heart attack. He was vice president and general manager of sulphur operations, Texas Gulf Sulphur Co. "In his daily rounds, attending to his duties of managing the business of mining sulphur, Harry Swem made every man he came in contact with feel that he was a sincere friend as well as the 'boss.' This was done simply, sincerely, without flattery, for he was known as a plain-spoken man. 'Safety' was practically a hobby with him and he deserves a great deal of the credit for the safety record established at TGS."

Mr. Swem was born in 1890 in Denver, the son of James Madison Swem, who was interested in mining in various parts of the West. His summer vacations during high school and college years were spent mining copper. After majoring in geology


Necrology

Date Elected	Name	Date of Death
1935	Thos. Gayleon Andrews	July 1954
1937	Max W. Ball	Aug. 28, 1954
1941	Stanley Barber	July 31, 1954
1953	Ali De Szepešy Schaurek	May 1954
1928	William Harkes	Aug. 11, 1954
1918	James O. Lewis	June 15, 1954
1920	Keith Roberts	Mar. 16, 1954
1918	Frederick LeV. Serviss	July 22, 1954
1920	Harry A. Swem	Aug. 8, 1954
1920	George H. Taber, Jr.	Aug. 30, 1954
1936	Seton S. Williams	May 26, 1954
1927	Clifford S. Wilson	May 1954

and mining at Stanford University, Mr. Swem worked as a junior engineer for Nevada Consolidated Copper Co. From 1914 to 1916 he was in Chile as assistant engineer for Chile Exploration Co. He returned to Nevada Consolidated Copper Co. in 1916, leaving in 1918 for service in World War I as a lieutenant in the 106th Engineers, 31st Div. Mr. Swem joined Texas Gulf Sulphur Co. in 1919 and died on the 35th anniversary of his first employment with this company.

Seton S. Williams (Member 1936) died May 26, 1954 from coronary thrombosis following a mine examination. He was a consulting mining geologist and engineer of Tucson, Ariz. Mr. Williams was born in Boston in 1914 and received his AB from Harvard University in 1936. He also studied at MIT from 1936 to 1937 and at the University of Arizona from 1946 to 1948. Mr. Williams was with the engineering dept., Phelps Dodge Co., Copper Queen Branch, Bisbee, Ariz., from 1937 to 1940. He worked successively as assistant ventilation and dust control engineer and mine engineer for the Junction Div. and as junior geologist for the entire branch. He then spent six months in charge of a preliminary industrial dust survey for the State of Arizona. During World War II he served with the U. S. Navy as a line officer in the net defenses in the Pacific and later as a navigator U.S.S. *Marblehead*. He was a commander when he retired in 1946. Among other companies, Mr. Williams was a consultant geologist for Charles Pettinos Inc.; Trust Dept., Southern Ohio Savings Bank & Trust Co.; and Walnut Canyon Mining Co.

SuperDuty
DIAGONAL DECK
No. 6
CONCENTRATOR
TABLE



Only A Cow Should Chew its Cud

Cud chewing may be very advantageous for a cow, but in the concentration of minerals it is costly and mechanically inefficient.

The SuperDuty DIAGONAL-DECK Concentrating Table eliminates unnecessary cud chewing by greatly reducing middlings rehandling by the table while producing higher grade concentrates and leaner tailings.

Send for Bulletin 118-B.

THE DEISTER CONCENTRATOR COMPANY
The Original Deister Co., Incorporated 1906
923 Glasgow Ave. Fort Wayne, Ind. U.S.A.

Proposed for Membership MINING BRANCH, AIME

Total AIME membership on Aug. 31, 1954 was 21,327; in addition 1724 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; R. B. Capies, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gersamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, Sidney Rolfe, J. H. Scaff, John T. Sherman, F. T. Staco, Frank T. Weems, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arisana

Morenci—Runyon, John B. (A)
Phoenix—Fletcher, Frank X. (A)
Phoenix—Swartz, Tench G. (A)

Colorado

Denver—Connors, Hugh M. (R. M)

Illinois

Chicago—Sayre, Paul L. (A)
Ottawa—Gerdling, Paul A. (M)
Ottawa—Gyger, Wayne B. (M)

Minnesota

Babbitt—Ahlquist, H. Richard (A)
Chisholm—Grant, Charles H. (J)
Elcor—Coughlin, Daniel E. (M)
Hibbing—Holland, Norman G. (M)
Hibbing—Sponberg, Edwin C. (M)

New Mexico

Santa Fe—Pollock, Martin W. (M)

Ohio

Columbus—Amos, Fred C. (J)
Painesville—Lefond, Stanley J. (R. C/S—A-M)

Oregon

Eugene—Leonard, Theodore (M)

Pennsylvania

Pittsburgh—Fyle, Paul P. (M)
Tamaqua—Pinkey, Leonard A., Sr. (A)

Utah

Midvale—Ross, Albin M. (A)
Salt Lake City—Wilson, Lowry M. (M)

Virginia

Max Meadows—Blair, John C. C., Jr. (M)

Wisconsin

West Allis—Greenwall, Richard B. (J)

Argentina

Mendoza—Monchablon, Alberto H. (M)

Australia

Broken Hill, N.S.W.—Stevens, Donald C. (J)
Sydney, N.S.W.—Van De Plasse, Jacobus M. (M)
Adelaide, South Australia—Bosher, Peter A. (C/S—J-M)

British West Indies

Jamaica—Blest, Raymon C. (A)

Canada

Ontario, Jamestown—Palmer, Russel F. (M)
Quebec, Duparquet—Patton, Francis E. (R. M.)

Cuba

Matanzas, Prov. Pinar de Rio—Nelson, Arthur P. (M)
Santiago de Cuba—Petrovsky, William J. (M)
Colony of Fiji, Vatukoula—Cernohorsky, Walter O. (J)

Peru

Huancayo—Fernandez, Cesar J. (J)
Huancayo—Osorio-Alfaro, Carlos (M)
Lima—Haleski, Joseph L. (M)
Lima—Horna, Eliseo F. (M)
San Juan Bay—Cabrera, Victor R. (J)

South Africa

Johannesburg—Van Der Merwe, Ockert T. (M)

Appraisals
Assayers
Chemists
Construction
Consulting
Designing

Professional Services

Space limited to AIME members or to companies that have at least one member on their staffs. One inch, \$40 per year; half inch, \$25 payable in advance.

ADAIR, BAILEY & VAN HORN
Minerals Consultants
Geology Mining Ore Dressing
Box 221, Murphy, N. C.

JAMES A. BARR
Consulting Engineer
Mt. Pleasant, Tennessee

BEHRE DOLBEAR & COMPANY
Consulting Mining Engineers
and Geologists
11 Broadway New York 4, N. Y.

BLANDFORD C. BURGESS
Registered Professional Engineer
Mining Consultant
Monticello, Georgia

COWIN & CO.
Mining Engineers and Contractors
Consulting Shaft & Slope Sinking
Appraisal Mine Development
Reports Mine Plant Construction
1-18th St. S. W. B'ham, Ala., Phone 56-5566

RENE ENGEL
Consulting Geologist
1333 Blair Avenue
South Pasadena, California
Telephone: ALbany 0912

GEORGE A. HOCH
Thin Section Technician
Standard and Oriented Sections
Unconsolidated Materials a Specialty
Dept. of Geology
Franklin & Marshall College, Lancaster Pa.

CARLTON D. HULIN
Mining Geology
26th Floor San Francisco 4
Shell Building California

C. P. KEEGEL
Mining and Metallurgical Engineer
Administration Appraisal
Specializing in Management and
Consultation in Latin America
707 South 6th St., Las Vegas, Nevada
Telephone 571

KELLOGG KREBS
Mineral Dressing Consultant
564 Market St., San Francisco 4, Calif.

LEDOUX & CO. INC.
Chemists Assayers Spectroscopists
SHIPPERS REPRESENTATIVES
380 Alfred Ave., Teaneck, New Jersey

JOSEPH T. MATSON
CONSULTING MINING ENGINEER
Examinations—Appraisals
Operations
P. O. Box 170 Santa Fe, New Mexico

CLAYTON T. McNEIL, E. M.
Consulting Mining Engineer
823 Bank of America Bldg.
Tel. GARfield 1-2948
SAN FRANCISCO 4, CALIFORNIA

JUNE M. METCALPE
CONSULTING EDITOR-WRITER
Books, Brochures, Mining and
Industrial Histories a Specialty.
88 Morningside Drive, N. Y. 27
Univ. 4-0200

ARNOLD H. MILLER
Consulting Engineer
Mine, Mill and Industrial Investigations
Improvement Design and Recommendations
Cable: "ALMEL" Tel. Cortlandt 7-0635
120 Broadway New York 6, N. Y.

RODGERS PEALE
Consulting Mining Geologist
318 Montgomery St.
San Francisco 4, Calif.

CHESTER M. F. PETERS
Mining Geology
Evaluations, exploration
and development programs
Colorado Plateau and adjacent areas
930 E. 3rd. South Salt Lake City, Utah

AMEDEE A. PEUGNET
CONSULTING MINING ENGINEER
Telephone MAIN 1-1431
705 Chestnut St. St. Louis 1, Mo.

LUCIUS PITKIN, INC.
Mineralogists
Assayers—Chemists—Spectroscopists
Shippers' Representatives
PITKIN BLDG., 47 FULTON ST., NEW YORK
Cable Address: Niktip

WILLIAM HELD PRATT
Geologist
Engineering Geology—Mining Geology
418 39th Ave. San Francisco 21, Calif.

MILNOR ROBERTS Consulting
Mining Engineer
The Pacific Northwest,
British Columbia and Alaska
4501 15th Ave., N.E. Seattle, Wash.

WILLIAM J. SHEDWICK, JR.
Mine and Geologic Reports
Mexico and Latin America
New Jersey License 2744-g
Reforma 20-302 Mexico 1, D.F.

CLOYD M. SMITH
Mining Engineer
Mine Examinations
Ventilation Surveys
Munsey Building Washington 4, D.C.

SPANSKI and WILLIAMSON
Geologists—Engineers
Groundwater Exploration
Engineering and Geological
Investigations
P.O. Box 151 Springfield, Ill.

H. W. STRALEY
Geology Geophysics
Box 68, Princeton, West Va.
1635 West Wesley Rd., NW, Atlanta, Ga.
CHerokee 6145

GODFREY B. WALKER
Metallurgical Consultant
Mineral Dressing & Extractive
Metallurgy
Heavy Media a Specialty
27 Lockwood Drive Old Greenwich, Conn.

O. W. WALVOORD CO.
Mill-Design and Construction
401 High St. Denver 2, Colo.

CLIFFORD R. WILFLEY
Consulting Mining Engineer
2233 Grape St. Denver 7, Colorado

HARRY J. WOLF
Mining and Consulting Engineer
Examinations—Valuations—Management
One Park Place, New York 17, N. Y.
Cable: MINEWOLF Tel: Rector 2-5307

ALFORD, MORROW & ASSOCIATES
CONSULTING ENGINEERS
Coal Mine Operation, Preparation
Prospecting and Development
Property Valuation
Oliver Bldg. Pittsburgh 22, Pa.

ALLEN & GARCIA COMPANY
42 Years' Service to the
Coal and Salt Industries as Consultants,
Constructing Engineers and Managers
Authoritative Reports and Appraisals
332 S. MICHIGAN AVE., CHICAGO
120 WALL ST., NEW YORK CITY

B. B. R. DRILLING CO.
National Road West
St. Clairsville, Ohio
Diamond Core Drilling
Contractors
Mineral Foundation
Cores Guaranteed Testing

CENTENNIAL DEVELOPMENT CO.,
Inc.
Eureka, Utah
Tel. 172
Consulting Mining Engineers
and Contractors
Shaft Sinking — Tunnel Driving
Mine Development
H. B. Spencer James Quigley

EAVENSON, AUCHMUTY & SUMMERS
MINING ENGINEERS
Mine Operation Consultants
Coal Property Valuations
3720 Koppers Bldg. Pittsburgh 19, Pa.

FAIRCHILD AERIAL SURVEYS, INC.
Airborne Magnetometer & Gradiometer
Surveys, Topographic Mapping, Aerial
Photography, and Photographic Mosaics
for Mining Exploration.
224 E. 11th St. 30 Rockefeller Plaza
Los Angeles New York

FETTERMAN ENGINEERING CO.
Civil & Mining Engineers
Consultants
Coal Mining—Property Valuations
Domestic & Foreign Examinations, Reports
Prospecting, Surveying, Mapping
Mine and Plant Layouts
Bank & Trust Building Johnstown, Pa.

Geo-Research
Geology Geophysics Mineralogy
Consultants
A Division of the
Institute of Industrial Research
SYRACUSE 10, N. Y. PHONE: 4-6454

T. W. GUY
Consulting Engineer
Coal Preparation
To Yield Maximum Net Return
Face and Product Studies
Plant Design and Operation
Kanawha V. Bldg. Charleston, W. Va.

ABBOT A. HANKS, Inc.
ASSAYERS-CHEMISTS
Shippers Representatives
624 Sacramento Street
SAN FRANCISCO

DIAMOND CORE DRILLING
BY CONTRACT
and world's largest manufacturer
Core and grout hole drilling in coal,
metal, and non-metallic deposits, both
surface and underground.
JOY MANUFACTURING CO.
Contract Core Drill Division
Michigan City, Indiana

E. J. LONGYEAR COMPANY
Consulting Mining Engineers
and Geologists
Contract Core Drilling
Diamond Core Drills and Supplies
Foshay Tower Minneapolis 2, Minn.

ROBERT S. MAYO
Civil Engineer Lancaster, Pa.
Specializing in Concrete Lining of
Tunnels. Haulageways and Shafts.
Special Equipment for Subaqueous
Construction.

R. S. MC CLINTOCK
DIAMOND DRILL CO.
Spokane, Wash. — Globe, Ariz.
Diamond Core Drill Contractors
Manufacturer of Diamond Bits and
Drilling Accessories

JOHN F. MEISSNER ENGINEERS, INC.
Consulting Engineers
Conveyor Systems Storage Methods
Crushing Plants Ship Loading Docks
Materials Handling and
Processing Plants
308 W. Washington St. Chicago 6, Ill.

DIAMOND CORE DRILLING
CONTRACTORS
Testing Mineral Deposits
Foundation Borings
MOTT CORE DRILLING CO.
Huntington, W. Va.

PENNSYLVANIA DRILLING
COMPANY
PITTSBURGH 20, PA.
DRILLING CONTRACTORS and
MANUFACTURERS
We prospect coal and mineral land
anywhere in North and South America.
Core borings for foundation testing;
dams, bridges, buildings, etc.

PRODUCTION AND MANAGEMENT
SPECIALIST
ROGER V. PIERCE
Underground Mining Methods, Cost
Cutting Surveys—Production Analysis
—Mine Mechanization—Mine Manage-
ment.
808 Newhouse Bldg. Phone 33978
Salt Lake City 4, Utah

PIERCE MANAGEMENT, INC.
MINING ENGINEERS
A Background of 27 years of Design,
Consulting and Management Service
to Coal and Mineral Industries in 38
States and 18 Foreign Countries.
Seranton Electric Bldg., Seranton 3, Pa.
1035 Connecticut Ave., N. W.
Washington 6, D. C.

RESEARCH, INC.
Exploration Research and Service
for the Mineral Industries
Geology Geochemistry Geophysics
Trace element analysis of soil
and rock samples
1511 Levee Street
Dallas 7, Texas Phone Riverside 3395

M. G. SMERCHANSKI
Consulting Mining Geologist
Registered Professional Engineer
Examinations, Geological Surveys
& Development
411 Childs Bldg. Winnipeg, Manitoba
Phone: 926323

SPRAGUE & HENWOOD, Inc.
SHEANTON 3, PA.
Diamond Drill Contractors and
Manufacturers
Core borings for testing mineral
deposits in any part of the world.

H. L. TALBOT
Consulting Metallurgical Engineer
Extraction and Refining of Base Metals
Specializing in Cobalt and Copper
Room 331, 84 State Street
Boston 9, Mass.

UNITED GEOPHYSICAL COMPANY, INC.
Serving the mining industry with gravi-
metric, electromagnetic, magnetic and
seismic surveys. United emphasizes con-
tinuous - recording - magnetic (MoMag)
and electromagnetic surveys employing
advanced-design equipment developed
and constructed at United's laboratories.
1200 S. Marengo Ave., Pasadena 15, Calif.

PAUL WEIR COMPANY
Mining Engineers and Geologists
Consultants and Managers
Design and Construction
20 No. Wacker Drive Chicago 6, Ill.

J. W. WOOMER & ASSOCIATES
Consulting Mining Engineers
Modern Mining Systems and Designs
Foreign and Domestic Mining Reports
Union Trust Bldg., Pittsburgh, Pa.
National Bank Bldg., Wheeling, W. Va.

WORLD MINING CONSULTANTS,
INC.
Consulting Mining Engineers
and Geologists
220 Broadway, New York 38, N. Y.
Worth 2-2934

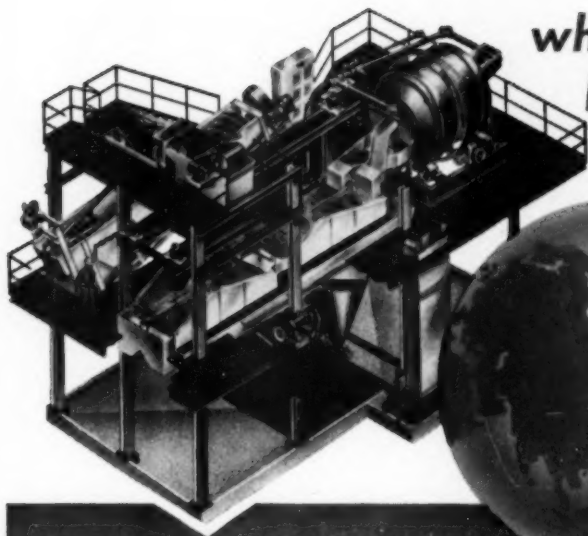
Coming Events

- Oct. 14-16, New Mexico Mining Assn. and El Paso International Mining Assn., joint convention, Carlsbad, N. M.
- Oct. 14-16, Drilling Symposium, University of Minnesota, Minneapolis.
- Oct. 17-20, AIME Petroleum Branch, Plaza Hotel, San Antonio.
- Oct. 18, AIME Columbia Section, Spokane, Wash.
- Oct. 18-22, American Society of Civil Engineers, annual meeting, Hotel Statler, New York.
- Oct. 18-22, National Safety Congress and Exposition, Chicago, Ill.
- Oct. 22-23, AIME, North Carolina Subsection of the Southeastern Subsection, fall field meeting, Durham, N. C.
- Oct. 26, Assn. of Consulting Chemists and Chemical Engineers Inc., annual symposium and banquet, Hotel Belmont Plaza, New York.
- Oct. 27-29, Clay Mineral Technology, Third National Clay Minerals Conference, Rice Institute, Houston.
- Oct. 28-29, Engineers' Council for Professional Development, Hotel Aims, Cincinnati.
- Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.
- Oct. 29, AIME, NOHC and Pittsburgh Local Section, off-the-record meeting, William Penn Hotel, Pittsburgh.
- Oct. 29-30, AIME, Industrial Minerals Div., Rocky Mountain Region Industrial Minerals Conference, Salt Lake City. Registration Oct. 28.
- Oct. 30, AIME, Utah Section, annual fall cocktail party, dinner dance, 7:00 pm, Newhouse Hotel, Salt Lake City.
- Nov. 1-3, AIME, Institute of Metals Div., fall meeting, Hotel Morrison, Chicago.
- Nov. 1-3, Geological Society of America and Associated Societies, Statler and Bltmore hotels, Los Angeles.
- Nov. 5-6, AIME National Open Hearth Conference, Southern Ohio Section, Deshler-Hilton Hotel, Columbus, Ohio.
- Nov. 5-6, AIME Central Appalachian Section, annual meeting, Homestead, Hot Springs, Va. Joint meeting with West Virginia Coal Mining Institute.
- Nov. 8-11, American Petroleum Institute, 34th annual meeting, Conrad Hilton Hotel and Palmer House, Chicago.
- Nov. 12, Illinois Mining Institute, Hotel Abraham Lincoln, Springfield, Ill.
- Nov. 12-13, AIME, Southeast Section, fall field meeting, Atlanta.
- Nov. 15-17, Dallas Council on World Affairs, conference on U. S. raw material needs, Dallas.
- Nov. 18, AIME, Utah Local Section, joint meeting with Intermountain Assn. of Petroleum Geologists, 8:00 pm, Newhouse Hotel, Salt Lake City.
- Nov. 18, American Mining Congress, Coal Div., Wm. Penn Hotel, Pittsburgh.
- Nov. 18-19, Society of Exploration Geophysicists, 8th annual Midwestern meeting, Adolphus Hotel, Dallas. Registration Nov. 17.
- Nov. 28-Dec. 3, American Society of Mechanical Engineers, annual meeting, Hotel Statler, New York.
- Dec. 1-3, AIME Electric Furnace Conference, William Penn Hotel, Pittsburgh.
- Dec. 12-15, American Institute of Chemical Engineers, annual meeting, Statler Hotel, New York.
- Dec. 20-31, American Assn. for the Advancement of Science, national meeting, University of California, Berkeley, Calif.
- Feb. 3-5, 1955, Colorado Mining Assn., annual meeting.
- Feb. 14-17, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.
- Mar. 28-Apr. 1, Ninth Western Metal Exposition, Pan-Pacific Auditorium, and Ninth Western Metal Congress, Ambassador Hotel, Los Angeles.
- Apr. 18-19, Third National Air Pollution Symposium, Pasadena, Calif.

Advertisers' Index

Allis-Chalmers Mfg. Co., General Machinery Div. _____	969	Houston Technical Laboratories _____	*
Compton Advertising, Inc. _____		Don L. Baxter, Inc. _____	
Allis-Chalmers Mfg. Co., Tractor Div. _____	958-959	Ingersoll-Rand Co. _____	*
Bert S. Gittins Adv. _____		Rickard & Co. _____	
American Cyanamid Co. _____	964A	International Nickel Co., Inc. _____	*
James J. McMahon, Inc. _____		Marachalk & Pratt Co. _____	
American Manganese Steel Div. _____	*	Jeffrey Mfg. Co. _____	953
American Brake Shoe Co. _____		Byer and Bowman _____	
Fuller & Smith & Ross, Inc. _____		Joy Mfg. Co. _____	963
Anaconda Copper Mining Co. _____		Walker & Downing _____	
Kenyon & Eckhardt, Inc. _____		Le Roi Co. _____	944, 945
Armour & Co. _____	*	Hoffman & York, Inc. _____	
Foots, Cone & Belding _____		Metal Carbides Corp. _____	*
Aros Electric, Inc. _____	*	Meek and Thomas, Inc. _____	
Bucyrus-Erie Co. _____	955	Mine & Smelter Supply Co. _____	951
Bert S. Gittins Adv. _____		Walter L. Schump, Advertising _____	
Cape Ann Anchor & Forge Co. _____	*	Mine Safety Appliances Co. _____	Fourth Cover
Caterpillar Tractor Co. _____	972	Ketchum, MacLeod & Grove, Inc. _____	
N. W. Ayer & Son, Inc. _____		Nordberg Mfg. Co. _____	946
Chain Belt Co. _____	964B	Russell T. Gray, Inc. _____	
The Buchen Co. _____		Northern Blower Co. _____	954
Colorado Fuel & Iron Corp. _____	952	Carr Liggett Adv. _____	
Doyle, Kitchen & McCormick, Inc. _____		Phelps Dodge Refining Co. _____	*
Copco _____	960	The House of J. Hayden Twiss _____	
J. J. Gibbons, Ltd. _____		Precision Radiation Instruments, Inc. _____	942
Deister Concentrator Co. _____	1033	The McCarty Co. _____	
Louis B. Wade, Inc. _____		Sauerman Bros., Inc. _____	1030
DeLong Corp. _____	*	Symonds, MacKenzie & Co. _____	
The McCarty Co., Inc. _____		Sheffield Steel Co. _____	1031
Denver Equipment Co. _____	*	R. J. Potts-Calkins & Holden Adv. _____	
Bill Bonals Adv. _____		Sintering Machinery Corp. _____	948
Detroit Diesel Engine Div. _____	949	Spooner & Krieger _____	
Kudner Agency, Inc. _____		Smidth & Co., F. L. _____	*
Diamond Products, Inc. _____	*	The Stuart Co. _____	
Ritchie & Sattler, Inc. _____		Sprague & Henwood, Inc. _____	1027
Dorr Co., The _____	943	Frederick B. Garrahan Adv. _____	
Sutherland-Abbott Adv. _____		Stearns-Roger Mfg. Co. _____	*
Dow Chemical Co., The _____	*	Gray & Co., Inc. _____	
MacManus, John & Adams, Inc. _____		Stephens-Adamson Mfg. Co. _____	1025
Dwight-Lloyd, Inc. _____	948	Glenn, Jordan, Stoetzel Inc. _____	
Spooner & Krieger _____		Texas Gulf Sulphur Co. _____	1028
Eimco Corp., The _____	965, 968	Sanger-Funnell, Inc. _____	
Matate Co. _____		Traylor Engrg. & Mfg. Co. _____	1022
Gardner-Denver Co. _____	*	The William B. Kamp Co. _____	
The Buchen Co. _____		Tyler Co., W. S. _____	1024
General Electric Co. _____	*	United Geophysical Co. _____	*
G. M. Basford Co. _____		Doxler-Eastman and Co. _____	
Hardinge Co., Inc. _____	1032	United States Rubber Co. _____	*
The W. H. Long Co. _____		Fletcher D. Richards, Inc. _____	
Hercules Powder Co. (Explosives) _____	*	Western Machinery Co. _____	Third Cover
Fuller & Smith & Ross, Inc. _____		Boland Associates _____	
Hercules Powder Co. (Flotation) _____	1026	Wilfley & Sons, Inc., A. R. _____	Second Cover
Fuller & Smith & Ross, Inc. _____		Ed M. Hunter & Co. _____	
Hewitt-Robins, Inc. _____	*	Wilmot Engineering Co. _____	1029
Fuller & Smith & Ross, Inc. _____		Wilbur A. Myers Adv. _____	
Heyl & Patterson, Inc. _____	947	Yuba Mfg. Co. _____	*
Dan A. Sullivan Adv. _____		Geo. C. McNutt Adv. _____	

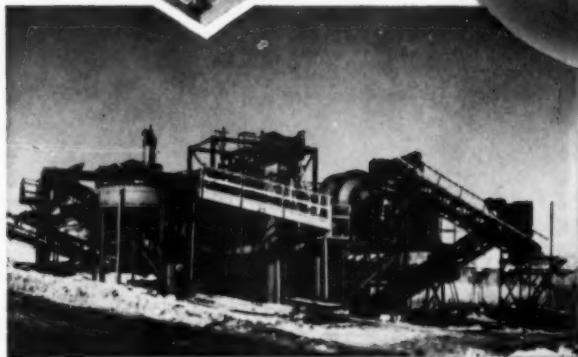
* Previous Issues



when you consider
HEAVY MEDIA SEPARATION
remember:



OVER 50%
of all
HMS PLANTS
are
WEMCO
MOBIL-MILLS



CUSTOM BUILT PLANTS

Wemco's extensive engineering and equipment experience is your assurance of our ability to design and install complete custom built beneficiation plants for any type mineral amenable to concentration by Heavy-Media Separation.

RENT OR PURCHASE WEMCO MOBIL-MILLS

Take advantage of Wemco's rental, rental/option to purchase, or outright purchase plans.

Write today for Bulletin M-3-M-5 and further information on the use of Mobil-Mills in mineral engineering practices.

Approximately 185 Heavy-Media plants have been placed in operation or are under construction throughout the world. Of these, 100 are Wemco Mobil-Mills located in 18 states and 15 foreign countries and having an aggregate rated capacity of 50 million tons annually. Here is remarkable proof of Wemco's design know-how and extensive experience in the Heavy-Media Separation field.

Consistent, economical concentration of ores amenable to Heavy-Media Separation is offered by the Wemco Mobil-Mill. The superior design of this unit gives accurate control of media density and positive sink removal. It assures higher grade concentrate and lower tailings with operating costs as low as 15 cents per ton of feed. A partial list of ores being efficiently treated by Wemco Mobil-Mills includes:

**LEAD
ZINC
IRON
FLUORSPAR**

**COPPER
DOLOMITE
BARITE
BRUCITE**

**MANGANESE
COAL
AGGREGATES
DIAMONDS**

Mobil-Mills • Coal Spirals • HMS Thickeners • HMS Pumps • Sand Pumps • Agitators
Cone Separators • Drum Separators • Hydroseparators • Fogargren Laboratory Units
Fogargren & Steffensen Flotation Machines • S-H Classifiers • Attrition Machines
HMS Laboratory Units • Dewatering Spirals • Thickeners • Conditioners • Denifiers

WEMCO
WESTERN MACHINERY COMPANY

760-766 FOLSOM STREET - SAN FRANCISCO 2, CALIFORNIA

PRINCIPAL OFFICES

San Francisco • Sacramento • Salt Lake City • Spokane
Denver • Phoenix • Chicago • Hibbing, Minnesota • New York
Birmingham • Toronto, Canada • Jeffersonville, Indiana

EXPORT DISTRIBUTORS

Fraser & Chalmers (S.A.) (Pty.) Limited, P.O. Box 619 Johannesburg, South Africa
Lilastone & Co., Inc., P.O. Box 3368, Manila, Philippines
United Development Corporation Pty. Ltd., P.O. Box 3460, Sydney, N.S.W., Australia
Corporacion Commercial Sudamericana S.A., Casilla 903, Lima, Peru
The Sumitomo Machinery Co., Ltd., 3-22 Kitakuma, Higashi-Ku, Osaka, Japan

Check these important MOBIL-MILL features

- Prefabricated, ready to install.
- Fast installation at the plant site.
- Minimum initial and operating costs.
- Clean separation, higher recovery.

Mobil-Mills are furnished in five basic sizes and several models with smaller or larger plants varying in capacity from 5 to 275 TPH. Each plant is equipped with a choice of one of the following type separators to meet your particular requirements:

- 1 **WEMCO SINGLE DRUM** gives positive sink removal and efficient control of media density for one stage separation over a wide range of size fractions.
- 2 **WEMCO TWO-COMPARTMENT DRUM** gives two stage separation in a single unit for treating ores having a middling component.
- 3 **WEMCO CONE SEPARATOR** gives efficient, low cost separation with ores where a finer range of feed sizes requires greater volume of medium.



He helped light the way to Safety
FOR MINERS EVERYWHERE

This month, the nation marks the 75th anniversary of Thomas A. Edison's invention of the first practical incandescent lamp. Giving added luster to this celebration is another of his great inventions . . . the first safe cap lamp for miners. Because his lamp eliminated the principal cause of mine fires and explosions—the open flame lamp—Edison called it his “most humanitarian invention.”

M.S.A. has been world distributor of Edison Lamps since their introduction in 1915. Working with Edison Laboratories ever since, M.S.A. has continued to improve efficiency and construction. The cumulative result of this combined activity is the present Edison R-4—100 times brighter than the first Edison lamp. The R-4's contribution to underground safety and production is written in the records of its many users.



When you have a safety problem, M.S.A. is at your service
... our job is to help you

MINE SAFETY APPLIANCES COMPANY

201 North Braddock Avenue, Pittsburgh 8, Pa.

At Your Service:

77 Branch Offices in the United States and Mexico

MINE SAFETY APPLIANCES CO. OF CANADA, LTD.

Toronto, Montreal, Calgary, Edmonton, Winnipeg,
Vancouver, Sydney, N.S.

